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AN ECOLOGICAL CATALOGUE OF THE CRAYFISHES BELONGING TO THE GENUS CAMBARUS, ... *J. Arthur Harris.*

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AN ECOLOGICAL CATALOGUE OF THE CRAYFISHES BELONGING TO THE GENUS CAMBARUS.

BY J. ARTHUR HARRIS.

With plates I to V.

INTRODUCTION.

DURING the last few years, much attention has been given to biological or ecological considerations in both botany and zoology, as one may easily convince himself by turning the pages of but a few volumes of current botanical or zoological journals. Concerning the importance of this work opinions are, naturally, greatly at variance. Some, in their enthusiasm, forget that ecological observations are valuable only as they contribute to our knowledge of the causes of the form and structure of the plant or animal body and the nature of its reactions to the conditions under which it exists, and fully merit the criticism of some of the older and more conservative morphologists and systematists, that ecology is a very superficial study. Others assign to the newer phase of scientific investigation its more nearly correct value, in regarding it as a very essential aid to an understanding of form and relationship. One can hardly deny the truth of the suggestion which may be offered by some, that ecologists are "making a mess" of the work they are trying to do, but those who have something of an acquaintance with the earlier morphological or taxonomic literature may at least suspect that the "ecological mess" is not the first one which has been made since men began recording their observations on plants and animals. There is in ecological work, and here possibly more than in almost any other field, an unfortunate tendency to build large and beautiful theories

on the smallest amount of data, and this is certainly deserving of criticism, but at the present time there need be offered no excuse for the publication or correlation of data of an ecological character, and little doubt that eventually, if they be carefully made, the observations will be of importance in the decision of really fundamental questions.

The paper embodied in the following pages has been sent to the press only after considerable hesitation, and since in some respects it is essentially different from the usual type of scientific publication, a few words of explanation, though not of apology, seem to be quite in place.

In the fall of 1898, at the suggestion of Prof. C. E. McClung, of the department of zoology, University of Kansas, I began studying the crayfishes to be found in the region around the University, and such material as I could obtain from other parts of the state. Being much interested in vegetable ecology at the time, I naturally was interested in the ecological phase of the new work. The most of my own observations have been published, but over two years ago I began to feel the importance of bringing together for a comparative study all that is known of the habits of the North American forms, and work was immediately begun by going through the literature and making abstracts of all parts of a biological nature. More recently I decided that the distribution of all the species should be presented in the same paper. The data are very meager and unsatisfactory, and I fully appreciate the fact that the necessary field-work has been only begun, and if it seemed possible for me to do further field-work I would not publish at the present time; but there seems little immediate hope of my being able to carry on the work in the way I would desire, and so it is deemed advisable to present the material brought together in as convenient a form as possible, in the hope that it may be of use to others more favorably situated for field observations, and perhaps serve as a nucleus or a suggestion for a much more extensive and valuable piece of biological work on this or some other genus.

In explanation of the purpose of portions of the paper, it seems desirable to mention in the briefest way some of the work which has been done on distribution in its more limited sense.

In 1850 Agassiz[1] noticed that there is a difference between

1. Agassiz, L. Lake Superior. Boston, 1850.

the species of fishes occurring in the upper and lower part of the courses of a stream, and in 1854[2] he pointed out more fully the importance of such investigations.

In 1868 Cope[3] studied the distribution of the fishes of the Alleghany region and arrived at several very important conclusions. Since that time various papers containing data and conclusions on the distribution of the fresh-water fishes have appeared,[4] and Jordan has presented[5] in detail the facts as they are known up to the present time.

More recently work of much interest has been done in plant and animal ecology. Cowles has published[6] a paper of great botanical interest in which he emphasizes the importance of the genetic and dynamic in physiographic ecology. The relation of biology to physiography has been emphasized in papers by Woodworth,[7] Hays and Campbell,[8] Simpson,[9] and Adams.[10] The results are well summarized by Adams.

The conclusions and suggestions in these papers, as well as of some others which have appeared, cannot be given in detail here, but those who are acquainted with them will understand my point of view in the compilation of the data dealing with the distribution by river systems. A single genus of a moderately large number of species of diverse habitat and wide distribution obviously offers advantageous material for a study of ecological adaptations—more favorable material for comparison than species taken from different genera.

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2. Agassiz, L. Am. Jour. Sci. and Arts, 2d ser., vol. XVII, p. 25, 1854. I have seen only quotations from this paper.

3. Cope, E. D. On the Distribution of the Fresh-water Fishes in the Alleghany Region of Southwestern Virginia. Jour. Acad. Nat. Sci. Phila., n. s., vol. VI, pp. 207–247, 1868.

4. Jordan, D. S. On the Distribution of Fresh-water Fishes. Am. Nat., vol. XI, pp. 607–613, 1877.

Jordan, D. S. On the Distribution of the Fishes of the Alleghany Region of South Carolina, Georgia, and Tennessee, with Descriptions of New or Little-known Species. Bull. U. S. Nat. Mus., vol. XII, pp. 7–95, 1878.

Forbes, S. A. A Catalogue of the Native Fishes of Illinois. Ann. Rep. Ill. Fish Com. 1884, pp. 60–89, 1884.

Jordan, D. S., and Gilbert, C. H. List of Fishes Collected in Arkansas, Indian Territory, and Texas, in September, 1884, with Notes and Descriptions. Proc. U. S. Nat. Mus. 1886, pp. 1–25, 1887.

5. Jordan, D. S. Science Sketches, new ed., Chicago, 1896.

6. Cowles, H. C. The Physiographic Ecology of Chicago and Vicinity: A Study of the Origin, Development and Classification of Plant Societies. Bot. Gaz., vol. XXXI, pp. 73–108, 145–182, 1901.

7. Woodworth, J. B. The Relation between Base-leveling and Organic Evolution. Amer. Geologist, vol. XIV, pp. 209–235, 1894.

8. Hays, C. W., and Campbell, M. R. The Relation of Biology to Physiography. Science, n. s., vol. XII, pp. 131–133.

9. Simpson, C. T. On the Evidence of the Unionidæ Regarding the Former Courses of the Tennessee and Other Southern Rivers. Science, n. s., vol. XII, pp. 133–136.

10. Adams ('01).

The habits of any species are necessarily directly dependent, in a great measure at least, upon the physical conditions under which it lives, and a knowledge of habits and habitat are necessarily so intimately connected that from a biological or ecological standpoint they cannot be separated. As our knowledge of the ecological relations of the species of a genus becomes more complete, we will be prepared to consider the structural peculiarities or adaptations of the different species, and so to have a much clearer idea of the origin and significance of specific characters.

That, in many groups, the time for these considerations, except in the more specialized cases, is not yet come, is perfectly evident. Furthermore, I am not at all unacquainted with a quite general revulsion to the too nearly universal tendency to see in every animal or plant structure some advantageous ecological adaptation, and in case direct observations do not furnish proof of such adaptation, either to explain its absence on the ground of insufficient knowledge of the living organism, or, as is too often the case, manufacture a pleasing theory in explanation. With many of the expressions of this feeling I am thoroughly in sympathy, but I cannot feel that the proper way of disposing of the matter is to characterize ecology as superficial or cheap and to ignore it entirely.

Systematic work, as the term is too generally interpreted—the description of species, the preparation of manuals with artificial keys, and "a list of species collected"—is certainly indispensable, but cannot be regarded as other than preliminary. In its better sense—the determination of the origin and relationship of species and groups, great and small—systematic work has an immense and vastly important field for the future. For this work the description and monographing of species and the preparation of faunal lists[11] is important and must precede other work, but it cannot be considered as the ultimate end of scientific investigation by any means. Much of the ecological work which is being done must be regarded in the same way—as preliminary work, the data of which will aid in the so-

11. Mr. Adams ('01) has expressed himself as follows: "The time is past when faunal lists should be the aim of faunal studies. The study must not only be comparative, but *genetic*, and much stress must be laid on the study of the habitat—not in a static, rigid sense, but as a fluctuating or periodical medium. The bearing of faunal studies upon the problem of differentiation and the origin of species is very close, and in our search for the factors we must not lose the perspective, and overlook those factors which are fundamental and work through long periods of time."

lution of greater problems. A knowledge of the habits or distribution of the species of a genus is not in itself of the greatest importance, but, if it enable us to determine something of the nature of structural adaptations to environment, it is contributing to the data for the solution of some of the problems of fundamental importance. The recognition of the fact that certain work is preliminary in nature, and that it is merely to furnish data for work of greater importance which would be incomplete or impossible without it, is not the slightest justification for the neglect of any field. Ecological questions are not the only ones, but a thorough knowledge of the ecological relations of the different species of a genus, in connection with a study of structural differences and a consideration of physiographic changes affecting distribution, will certainly contribute very greatly to a definite knowledge of some phases of evolution.

For several reasons *Cambarus* offers a particularly inviting field for ecological work. A more thorough knowledge of the habits of the animals may, possibly, contribute much to a full understanding of the very remarkable sexual dimorphism occurring in the adult males. Individual variation is very great and puzzling—so much so that Professor Stimpson is said to have remarked that either there is only one species of crayfish in eastern North America or each mud puddle has its own. The genus has certainly undergone a remarkable differentiation into species. There are now recognized nearly eighty species and varieties from the range of distribution in North America, as compared with about thirteen species of *Astacus*, the other genus of the crayfishes of the northern hemisphere, from Europe, Asia, and America. As Faxon has pointed out, this difference is not to be attributed to more thorough exploration of the American territory. The chances for addition of species by further exploration seem to be greatly in favor of *Cambarus* rather than *Astacus*. Doctor Faxon ('90) has said: "I have reason to believe that oftentimes in this genus mere varieties, coming into contact in a given locality, are perpetuated by breeding true, when, by extending our geographical range, every intermediate condition connecting the two forms will be found still surviving. Nowhere do we seem to come so near to seeing the process of evolution of species going on under our very eyes as in this genus *Cambarus*. It seems to me that the only criteria of a

species must be the amount and character of the variation, and the absence of intermediate forms, not in one locality alone, but over the whole area of distribution."

That the conditions of environment under which the different species of *Cambarus* are found are very diverse is apparent to any one who is acquainted in a general way with the physical features of different regions in which crayfish are known to occur. A study of these conditions and the adaptation of the animals to them may be expected to yield some interesting results.

While thoroughly convinced of the importance of an ecological study of the crayfishes, I recognize perfectly that for the majority of species of the genus it is as yet impossible to draw any conclusions at all as to the character of habitat or any adaptation to it, but we do know quite definitely in a few cases in what type of locality a given species may be found, and in some cases structural adaptations are very marked, and it is my hope that the arrangement of all the data so far secured in a convenient form for ecological work will shorten the time till our knowledge of these questions may be much more comprehensive than it is at present.

In the following pages is given, in as condensed a form as has been considered advisable, abstracts of all that has appeared on the habits of the different species, so far as it was regarded as worthy of notice, and a list of all the known localities of the species of *Cambarus*, with the drainage basin to which they belong. This has been compiled and presented as necessary data for a consideration of the ecological relations of any species, or group of species. While I feel that with our present knowledge of the subject generalizations are of little value, and have sought to indulge very temperately in conclusions, I have in some cases expressed my opinion as to the significance of the facts observed. The main purpose of the paper, however, is the compiling and recording in an easily accessible form of such biological data as have been secured up to the present time, in the hope that they may be of use to those who have better opportunities than I for further work along this line. Of some of the imperfections of the paper as it is here presented I am as fully aware as the most of those who may see it, but the

pressure of other work, as well as some other considerations, makes me feel that publication at the present time is desirable.

A few words of explanation of the arrangement of material may be in place here. The purpose of the paper being the presentation of data so far secured in easily accessible form, the arrangement is a purely artificial one. For convenience of reference the species are arranged alphabetically. Under each species is given a catalogue of all the localities from which it has been reported. In a catalogue of fresh-water animals prepared for ecological work, it is evidently better to have the material reported from streams rather than from cities, and I have given, so far as I have been able to determine from maps, the stream to which each lot of material probably belongs, or which drains the territory from which it was taken. This may seem to some an addition of little importance, since so far as the range of distribution of a species in a broad way is not affected by its occurrence in Nelson's creek or Big river, so long as it is known that it was taken near Pineville, in the eastern part of the state, but those who are acquainted with the aims of some phases of ecological work will fully appreciate the desirability of obtaining all bits of data, even though small and unsatisfactory. For the mere purpose of determining the drainage systems in which each species occurs, it has been necessary to go over the localities carefully, and it has been thought best to record the decision in each case. As a matter of convenience, the county has also been added when possible, all supplied material being enclosed in brackets. The states are arranged alphabetically and numbered, and under them the localities are numbered, so that cross-reference is made convenient. (*C. diogenes* 15.1 referring to the first locality for *C. diogenes* given under Kansas.)

Following the catalogue of localities is given a review of the material of an ecological nature which has appeared on the species under consideration. By means of summaries and tables at the end, it is the intention to bring together and compare points of similarity and dissimilarity in the different species. That the purely artificial arrangement is open to criticism I am fully aware, but it seems to me the best in a paper the object of which is merely the arrangement of data in convenient form

for future work. The natural arrangement of the species in the genus is as follows:

GROUP I.

C. blandingii, Ga., Md., Miss., N. J., N. Y., N. C., S. C., Tex., Va.
blandingii acutus, Ala., Ark., Ill., Ind., Ind. Ter., Iowa, La., Miss., Mo., N. C., Ohio, S. C., Tenn., Tex., Wis.
fallax, Fla.
hayi, Miss.
clarkii, Ala., Fla., La., Miss., Ohio, Tex.
troglodytes, Ga., Ill., S. C.
lecontei, Ala., Ga.
angustatus, Ga.
pubescens, Ga.
spiculifer, Ga.
versutus, Ala., Fla.
alleni, Fla.
evermanni, Ala.
barbatus, Ala., Ga., Miss., S. C.
wiegmanni, Mex.
pellucidus, Ind., Ky. (caves).
pellucidus testii, Ind. (caves).
acherontis, Fla. (caves).

GROUP II.

C. simulans, Kan., N. M., Tex.
mexicanus, Mex.
advena, S. Ga.
gracilis, Ill., Ind., Iowa, Kan., Mo., Ohio, Wis.
carinatus, Mex.
cubensis, Cuba.
hagenianus, S. C.
?clypeatus, S. Miss.

GROUP III.

C. bartonii, Can., D. C., Ga., Ind., Ky., Me., Md., Mass., Mo., N. J., N. Y., N. C., Ohio, Pa., R. I., S. C., Tenn., Vt., Va., W. Va.
bartonii robustus, Can., Ill., Md., N. Y., Pa., Tenn., Va.
bartonii longirostris, Ala., Tenn., W. Va.
longulus, N. C., Tenn., Va., W. Va.
carolinus, I. T., N. C., Pa., Tenn., Va., W. Va.

uhleri, Md. ("eastern shore").
latimanus, Ala., Ga., Miss., S. C., Tenn.
acuminatus, N. C., S. C.
extraneus, Ala., Ga., Tenn.
extraneus girardianus, Ala., Tenn.
jordani, N. Ga.
argillicola, Can., Ill., Ind., La., Mich., Miss., N. C., Ohio, Tex.
diogenes, Ark., Colo., D. C., Ill., Ind,, Iowa, Kan., Ky., Md., Mich., Minn., Miss., Mo., N. Y., N. C., Ohio, Pa., Tenn., Va., Wis., Wyo.
diogenes ludovicianus, La.
cornutus, Ky.
hamulatus, Tenn. (Nickajack cave).
setosus, S. W. Mo. (caves).

GROUP IV.

C. lancifer, Ark., Miss.
affinis, Lake Superior, Lake Erie, D. C., Md., N. J., N. Y., Pa., Va.
indianensis, S. Ind.
sloanii, S. Ind., Ky.
propinquus, Can., Ill., Ind., Iowa, Mich., N. Y., Ohio, Pa., Wis.
obscurus, N. Y., Pa.
propinquus sanbornii, Ky., Ohio.
neglectus, Ark., Iowa, Kan., Mo., Tex.
harrisonii, Mo.
virilis, Can., Ala., Ark., Ill., Ind., I. T., Iowa, Kan., Mich., Minn., Mo., Neb., N. Y., N. Dak., Tenn., Tex., Wis., Wyo.
immunis, Ala., Ill., Ind., Iowa, Kan., Mich., Minn., Mo., Neb., N. Y., Ohio, Wis., Wyo., Mex.
immunis spinirostris, Ind., Kan., Tenn.
hylas, Mo.
pilosus, Kan.
nais, Kan.
mississippiensis, Miss.
palmeri, Ark., Tenn.
palmeri longimanus, I. T., Tex.

longidigitus, Ark.
difficilis, I. T., Ark.
meekii, Ark.
erichsonianus, Ala., Tenn.
alabamensis, N. Ala.
compressus, N. Ala.
medius, Mo.
rusticus, Ala., Ark., Ill., Ind., Iowa, Kan., Ky., Mich., Mo., Ohio, Pa., Tenn., Tex., Wis.
spinosus, N. Ala., Ga., N. C., S. C., Tenn.
putnami, Ind., Ky., Tenn.
forceps, N. Ala., Va. Tenn.
digueti, Mex.

GROUP V.

C. montezumæ, Mex.
montezumæ dugesii, Mex.
montezumæ areolatus, Mex.
montezumæ occidentalis, Mex.
shufeldtii, La.
chapalanus, Mex.

PARASITISM IN CAMBARUS.

According to Moore ('93), various writers have discussed the Discodrilidæ parasitic on the European *Astacus fluviatalis*, and Whitman has considered those living on the crayfishes of Japan. He finds that our American forms carry about a "heterogeneous burden of leech-like parasites (or messmates?)," *C. bartonii* being affected by at least four easily distinguishable forms, while other and different forms have been found on *C. affinis*, and on a *Cambarus* sp. inhabiting the larger mountain streams of North Carolina. He presents descriptions of the species and some notes on their place of occurrence. The species and notes of interest in this place are the following:

Branchiobdella illuminata Moore, sp. nov. Very common, being found in the branchial chambers, which it never appears to leave except at the time of molt, during the life of the crayfish in nearly one-half the larger individuals of *C. bartonii* examined. Cocoons found throughout the year attached to the branchial filaments, especially the inner ones. Philadelphia, Pa., and Watauga county, North Carolina.

B. pulcherrima Moore, sp. nov. Cocoons usually attached to

broader surfaces of body, as sides of carapace, inner faces of anterior abdominal epimera, and external face of tail fin. Adults found attached almost anywhere on exterior of crayfish, but more especially on the tergal surfaces. On *C. bartonii*, Watauga county, North Carolina.

B. instabilis Moore, sp. nov. Cocoons usually attached to palmar surface of propodite of great chelæ. Animals largely restricted in distribution to the same segments of the limb; usually to be found in numbers clustered at the base of the pinchers, to which position the form of the body particularly adapts them; frequently wandering to other parts of the same limb, or even to the following pairs of ambulatory limbs. Watauga county, North Carolina, and Delaware county, Pennsylvania.

B. philadelphica Leidy. According to Leidy ('52), this species is found frequently in numbers from one to several dozen upon any part of the exterior of the body of *A. bartonii*, but more especially upon the interior surface and the branchiæ, but Moore ('93) never found it inhabiting the branchial chamber, but principally the sternal surface of the entire body, among the bases of the appendages. Cocoons attached to abdominal sternites, but more frequently to the setæ of pleopods; found principally in summer, but not entirely absent at any season. Philadelphia, Pa., and Watauga county, North Carolina.

Bouvier ('97) states that of the twenty specimens of *C. digueti* received four were attacked by *Temnocephala* and two carried a large number of *Branchiobdella*.

THE COLORS OF CAMBARUS.

Owing largely to the necessary condition of our museum material, very little is known of the colors of our crayfishes. In the systematic literature there are a few references to this characteristic in the descriptions of the species, but with these we are not concerned here.

Kent ('01) has recently published observations, for the most part on *C. immunis*, with some work on *C. propinquus*, *C. bartonii*, and *C. diogenes*, in which he concludes that in nearly all cases the color of the animals closely resembles that of the environment, being blue in color in a pond where the bottom was of blue clay, black where there was a muddy, black bot-

tom, and of different colors in other places. An exception to this was found in those of a red color. These were found entirely in the shallow water in small streams, and the writer concludes from this, and from experiments in which crayfishes in black, blue and green colors were changed to brown and red when kept in an aquarium exposed to light,[12] that the red color is due to the influence of the light. Specimens of different colors taken from different localities and kept in a zinc tub showed, after several months, in some cases a change of color to that of their surroundings. In April and May the coloration of the young crayfish was studied and the conclusion reached that the red color, due to large, scattered chromatophores of the young crayfish, changed to blue or black or underwent no change, according as the adults were blue, black, or red.

C. diogenes, he says, furnishes an excellent example of color change. The individuals of this species which, according to him, may be found in any of the smaller streams, in the early spring show various colors, but later in the year are nearly all red. They burrow during the winter, and come out in the spring much the color of the soil, and these colors are gradually turned to red in the open sunlight.

He concludes, then, that the colors of crayfish are due to two causes, the influence of environment and the effect of sunlight,[13] and that in all cases these colors serve as protection against enemies.

The question of coloration is by no means a simple one, and without opportunity for an examination of the literature, or more detailed observations than I have been able to make, I do not care to offer explanations, but may call attention to one or two facts which have come to my notice. The colors of a species are certainly not always the same when found in different localities, but I have never been willing to state that the difference should be regarded as a protective adaptation, although this might be the case. Mr. Kent states that the change in

12. Of this he says: "This is a difficult experiment to carry out. Crayfish which live in deeper water become strongly photopathic and can endure only very weak light. It was necessary at first to place the aquarium with the crayfishes in diffused light and to allow them to become accustomed by degrees to the changed conditions." It is unfortunate that he does not give in more detail the injurious effect of the light upon the animals. In nature some of the burrowing forms are exposed to light of considerable intensity upon emerging from their burrows in the spring. So far as has been recorded, the cave forms are not affected by exposure to light. Compare Putnam's observations on *C. pellucidus*.

13. He mentions in the first part of the paper the effect of sunlight in changing the color of pigment when removed from the animal, but, with the exception of heat, does not consider other factors which might produce this change.

color requires some weeks, or possibly months, of time, and that, since many species of crayfish are migratory, especially those living in running water, the color of those seen in small streams may not be at all like their environment, and that the best results may be obtained from a study of those in the small ponds, where migration cannot occur. Until our knowledge of the habits of this genus is much fuller than it is now, one should be careful in stating that many species are migratory in their habits, unless the terms are carefully limited.

The point in regard to the colors of *C. diogenes* is especially interesting. It will be noticed that the habits of the species as observed by Mr. Kent are quite different from those usually attributed to it, for it seems usually to occur in the open water for but a very limited part of the year. My observations on *C. diogenes* are not extensive, but in *C. gracilis* the females which are found in the open ponds for some time in the spring are of the same olive-green color during the entire period. In the very large series of material I have collected in open water I have never found an exception, nor did the two or three specimens I have taken from burrows late in the summer show any differences, but the four or five males, all first-form—the adult second-form not being known—were all of a beautiful salmon-red color, and in all cases I have every reason to believe they had just come from burrows, a point in which I am certain in two cases. The young of both sexes up to an inch and more in length show a coloration somewhat similar to that of the adult female. It is interesting to notice that, according to Faxon, *C. carolinus* (*C. dubius* Fax.), another of the burrowing forms, is known to the Indians in the Territory as "red crayfish," and that, according to Williamson ('01), it has, in Allegheny county, Pennsylvania, a very different color.

In this place the colors of the cave species need not be considered, since this is touched upon under the individual species. It would be interesting to examine the young in reference to the development of color, as has been done in the case of some of the cave-inhabiting fishes. For those who have the opportunity, be it for experimental or field observation, the colors of these animals certainly offer an interesting problem.

THE DIMORPHISM OF CAMBARUS.

The consideration of the very remarkable condition of a sexual dimorphism in the adult males of *Cambarus* is within the scope of the present paper in so far as it is connected with the breeding habits of the animals. The taxonomic importance of the existence of the two forms was pointed out by Doctor Hagen ('70) and has been since confirmed for every species of which a large series of males has been examined. Doctor Faxon ('84*b*) announced the true nature of the dimorphism as an alternation of forms in the individuals. Harris ('01*b* and '01*c*) confirmed Faxon's observations on a much more extensive series of material, finding that there are apparently exceptions to the rule of the alternation of the two forms in the adults, and made a cytological study of testicular material, showing that when the season at which material is secured is taken into consideration no marked difference in the essential reproductive organs of the two forms is observable. In *C. immunis*, and perhaps in *C. virilis* as well, the proportion of first-form males gradually increases in late summer and autumn, there being, so far as he could determine, no definite time for exuviation. In the spring the animals appeared in the open water early in March and all males taken up to April 15 were first-form, but in a very short time afterward nearly all the males had assumed the second-form condition. His study of a series of testes led him to the conclusion that so far as the presence of sexual elements is concerned the second-form is as capable of copulation as the first-form, and that in the adult the second-form condition probably represents the period in which the regeneration of the sexual elements for the most part takes place. He also points out the parallel between the alternation of forms in *Cambarus* as secured by spring and fall exuviation and the spring and autumn exuviation in the male of *Astacus* as described by European observers.

Hagen and Faxon considered that the second form is probably sterile, and the rudimentary condition of the external male organs, the pleopods and hooks on the legs (for a discussion of the function of these, see the section on conjugation) would certainly suggest this view, but the work on the microscopic structure of the testis leaves no doubt as to the presence of the spermatozoa in the same quantity, and apparently in the same

condition, as in the first-form. In a letter of October 29, 1901, Prof. W. P. Hay, of Washington, whose work on the crayfishes is well known, and whom I have to thank for various courtesies, says: "I think you are entirely correct in your observations, and have settled some points beyond doubt. I have long been of the opinion that males of the second-form are not sterile, for I have often seen them copulating, and, after the act was completed, have found masses of sperm on the sternites of the female. Of course, the spermatozoa might be inert, but such a condition would, so far as I know, be without parallel."

This observation of Professor Hay's I regard as important, considering the highly different physical characteristics of the two forms, their constant occurrence in all the well-known species of the genus, and the absence, so far as we now know, of such in the other genera of this family, unless it be in *Cambaroides*.

THE CONJUGATION OF CAMBARUS.

Mr. E. A. Andrews first published observations on this subject. In the American Naturalist he ('95) describes the process in detail, giving two figures from photographs. In the Zoologischer Anzeiger he gives (95*b*) about the same observations in condensed form. The following is quoted from his paper in the Zoologischer Anzeiger:

"Some observations on the breeding habits of *Cambarus affinis* show that there are important differences between the American crayfish, *Cambarus*, and the European crayfish, *Astacus*, and that certain structures hitherto known only as specific and generic characters are necessary accessory reproductive organs.

"1. When kept in confinement *Cambarus affinis* conjugated in November and in February, March, and April.

"2. The process lasts several hours.

"3. The male exhibits great skill and persistency, and is visibly excited throughout the process, while the female is from the first passive and inert and shows scarcely any evidence of excitement.

"4. The sperm is introduced into the cavity in the annulus, which thus serves as a sperm receptacle, as in the lobster,

Homarus americanus, as described by Professor Bumpus. (Journal of Morphology, V, 1891.)

"5. The well-known hook on the ischiopodite of the third walking leg of the male is used in the process of conjugation to firmly attach the male to the female. The tip of the hook depresses the membrane between the coxopodite and basiopodite of the fourth walking leg of the female, and the hook catches firmly against a stiff ridge on the basiopodite.

"6. The sperm is conveyed down the groove of the stylet or first pleopod of the male from the penis-like everted end of the vas deferens into the cavity of the annulus of the female. The annulus becomes filled and a plug of sperm and protective secretion projects from the orifice after conjugation.

"7. At a definite stage in the process, the male always passes either the right or left fifth, or last, walking leg across under the thorax so that it projects horizontally from the other side. The limb then holds the first and second pleopods, the intromittent apparatus, depressed at an angle of more than forty-five degrees from the ventral surface of the male, and this insures their entrance into the annulus when the male moves forward over the female.

"8. During the process the ventral sides of the two animals are closely applied to one another and the abdomen of the male partly encloses the abdomen of the female. The latter lies on the back or partly on one side and is firmly held by the large chelæ of the male which grasps all the chelate appendages of the female.

"9. There is no wide distribution of sperm as has been described for *Astacus;* it is all placed in the annulus. The oviducts of the female are not concerned in the process of conjugation.

"In the one case in which eggs were laid in captivity, the nervous system of the female was very irritable for several days. During the time, by assiduous labor with both of the fifth walking legs, she carefully removed all foreign matter from the ventral surface of the abdomen and from the pleopods.

"The sperm plug remained in the annulus for two days after the eggs were laid and then disappeared. It was probably removed by the female. The process was, however, abnormal and the eggs did not develop."

About a dozen cases were observed in the laboratory by Mr. Andrews. The entire process lasted from two to ten hours and might be repeated by either animal with some other. The two were so firmly united that it was perfectly easy to transfer them from one dish of water to another to examine the more minute details of the process with a hand lens. By throwing the animals into actively boiling water for a few moments he found it possible to fix them in their natural position, in which they may then be preserved indefinitely.

Shufeldt ('98) gives a figure of a pair of conjugating *C. affinis*. The figure much resembles those given by Andrews. Through the courtesy of Doctor Shufeldt, the figure is reproduced in plate I.

LIST OF SPECIES.

Cambarus acherontis Lonnberg.

8. Florida.

1. Lake Brantley, Orange county. (Lonnberg, '94.)
2. Gum Cave, Citrus county. (F., '98.)

This species was described by Doctor Lonnberg ('94) from Orange county, Florida. In digging a well, a subterranean rivulet was struck at a depth of about forty-two feet, after passing through sand and clay, and finally five feet of phosphate rock, bones and teeth of sharks, and a thin layer of hard limestone. At first the crayfish were quite numerous, but later, when Doctor Lonnberg visited the place, only the two types could be found.

Doctor Lonnberg considers that the age of the subterranean rivulet in which the crayfishes were found is probably Post-Pliocene or still younger. He considers the other caves in which blind *Cambari* have been found comparatively much older, and so thinks it is at least possible that *C. pellucidus* and *C. hamulatus* have a much greater phylogenetic age than *C. acherontis*.

The subterranean water-system of Florida must be, Doctor Lonnberg thinks, quite extensive. The ancestors of this species—probably *C. clarkii*—may have forced their way into the rivulet from its exterior mouth, or have more probably fallen in when one of the numerous sink-holes of the region was formed.

Cambarus acuminatus Fax.

32. North Carolina.

1. James river [Johns R.], Morganton [Burke county]. (F., '90.)
2. Swannanoa river, Black mountain [Buncombe county]. (F., '90.)
3. Neuse river, Raleigh [Wake county]. (F., '90.)
4. Reedy fork, Cape Fear river, Greenborough [Guilford county]. (F., '90.)
5. French Broad river [Madison or Buncombe county]. (F., '85.)
6. [Trib. Catawba R.], Old Fort, McDowell county. (F., '85.)

39. South Carolina.

1. Saluda river, west of Greenville [Greenville county]. (F., '85.)

According to Mr. John Tull, who is acquainted with the territory, the Johns river at Morgantown is a cold, clear, rocky, mountain stream, narrow and deep, swiftly flowing in most places. The Swannanoa river (32.2) is about the same in character, being possibly a little more rapid flowing. The Catawba river at Old Fort (32.6) is very similar to the Johns river at Morganton, although the two streams at Morganton, where they are about three miles apart, are very different in character, the Catawba being broader, shallower, more muddy, and not so cold.

The localities known, with two exceptions, indicate that this is an inhabitant of mountain streams. Its occurrence in the head waters of streams flowing into the Atlantic ocean and in the head waters of a tributary of the Tennessee river in the same mountains is interesting. Faxon states that the material from the French Broad river and McDowell county differs from the other, and may prove to be a distinct species.

Cambarus advena LeC.

9. Georgia.

1. "Habitat in Georgia inferiore. Hyeme vitam degit subterranean. Aestate in fossis invenitur." (LeConte, '56.)

Cambarus affinis Say.

? Lake Erie. (F., '85, and '90.)
Lake Superior. (F., '85.)

7. District of Columbia.

1. [Potomac R.], Washington. (F., '85.)

19. Maryland.

1. [Potomac R.], Montgomery county. (F., '85.)
2. Potomac river, Charles county. (F., '85.)
3. [Potomac R.], Williamsport, Washington county. (F., '85.)
4. [Potomac R.], Cumberland, Alleghany county. (F., '85.)
5. [Chesapeake bay], Anne Arundel county. (F., '85.)
6. [Patapsco R.], Gaynns Falls, Druid Hill, etc., Baltimore county. (F., '85.)
7. [Chesapeake bay], Cecil county. (F., '85.)

29. New Jersey.

1. [Trib. Delaware R., or Raritan R.], Schooley's Mountain, Morris county. (F., '85.)
2. [Delaware R.], Camden county. (F., '85.)
3. [Delaware R.], Trenton [Mercer county]. (F., '85.)
4. [Delaware R.], Burlington [Burlington county]. (F., '85.)
5. [Navesink R.], Red Bank, Monmouth county. (F. '85.)

31. New York.

1. [Niagara R.], Niagara [Niagara county]. (F., '85.)

37. Pennsylvania.

1. [Schuylkill R.?] [——— county]. (F., '85.)
2. [Trib. Delaware R.], Reading [Berks county]. (F., '85.)
3. [Delaware R.], Philadelphia [Philadelphia county]. (F., '85.)
4. [Trib. Susquehanna R.], Carlisle [Cumberland county]. (F., '85.)
5. [Susquehanna R.], Bainbridge [York county]. (F., '85.)
6. Susquehanna river. (F., '85.)
7. [Delaware R.], Bristol [Bucks county]. (F., '85.)
8. Brandywine creek [Chester county]. (F., '85.)

45. Virginia.

1. Potomac river, Gunston, Fairfax county. (F., '85.)
2. Shenandoah river, Waynesborough [Waynesboro], [Augusta county]. (F., 90.)
3. Blackwater river, Zuni [Isle of Wight]. (F., '90.)

Abbott ('73) characterizes this as "a deep water [as compared with *C. acutus*], stone-hunting form." In the neighborhood of Trenton, N. J., he found it usually resting under flat stones well out from the banks of the stream, where the water was of considerable depth, and also in fewer numbers on the mud-bottomed portions of the river. He found none among the vegetation, where *C. acutus* was abundant. There was nothing to indicate that it is a burrowing species.

Smith ('74) takes his material from Abbott ('73).

Faxon ('85) states that since Abbott's paper ('73) appeared Doctor Abbott and he have taken *C. affinis* in great numbers from shallow ditches in the Delaware meadows, near Trenton, N. J.,

in company with *C. blandingii*, and that, "According to Mr. P. R. Uhler, *C. affinis* is the common form in the warmer parts of the rivers and creeks of Maryland, underneath the stones. In his collection are specimens from Montgomery county labeled as found in stagnant pools, and specimens from Alleghany county, four miles below Cumberland, were taken from 'holes in the bottom and sides of a canal.'"

See, also, parasitism and Faxon ('85), under *C. pellucidus*.

Cambarus alabamensis Fax.

1. Alabama.

1. Second creek, Waterloo, Lauderdale county. (F., '85)

Cambarus alleni Fax.

8. Florida.

1. St. Johns river, Hawkinsville, Orange county. (F., '85.)
2. [Gulf drainage], Hernando county. (F., '85.)
3. Caloosahatchee river [Lee or Desoto county]. (F., '90.)
4. A little creek, Hillsborough county. (Lonnberg, '94.)
5. Small lakes around Apopka and several other places, Orange county. (Lonnberg, '94.)
6. Ditches and small ponds, Arcadia, Desoto county. (Lonnberg, '94.)

Lonnberg ('94) expresses the opinion that this is a form widely distributed in south Florida, and that *C. alleni* and *C. fallax*, having never been found outside of the state, have probably become differentiated as species there, and that their existence as such can, then, not extend farther back than to the Pliocene.

From the catalogue it will be seen that the distribution is quite extensive, and that they are found in the territory drained by both the Gulf of Mexico and the Atlantic.

Lonnberg ('95) says of *C. alleni* and *C. fallax* in Florida: "They lived in creeks, small lakes, and ponds, very often hiding in the rich vegetation there, or under logs, boards, and so on. Sometimes I found them digging holes on the shore, at low water, and these holes often went down to such a depth that the water came up into them."

C. alleni he took in October in a small creek in Hillsborough county, all the males being second-form. In Orange county, he found this species in small lakes around Apopka "and several other places." At Acadia, Desoto county, he took it in ditches and small ponds.

Cambarus angustatus LeC.

9. Georgia.

1. Le Conte ('56) says: "Habitat in Georgia inferiore, in aquæ puræ rivulos qui inter colleculos arenosus (sand-hills) currunt."

Cambarus argillicola Fax.

Canada.

1. [Lake Ontario], Toronto, P. O. (F., '85.)

11. Illinois.

1. Lowlands bordering on Wabash river, York, Clark county. (F., '90.)

12. Indiana.

1. [White R.], Irvington, Marion county. (Hay, '96.)
2. [White R.], Bloomington, Monroe county. (Hay, '96.)
3. [Trib. White R.], Wheatland, Knox county. (Hay, '96.)
4. [Trib. Ohio R.], New Albany [Floyd county]. (Hay, '96.)

17. Louisiana.

?1. [Mississippi R.], New Orleans [Orleans county]. (F., '85.)

21. Michigan.

1. [Trib. Lake St. Clair], Detroit [Wayne county]. (F., '85.)
2. [Trib. of Shiawassee R.], East Saginaw [Saginaw county]. (F., '85.)

23. Mississippi.

1. Bay St. Louis, Hancock county. (F., '98.)

32. North Carolina.

?1. [Neuse R.], Kinston, Lenoir county. (F., '85.)

34. Ohio.

1. Kelley's island, Lake Erie. (F., '90.)
2. [Trib. Lake Erie], Oberlin [Lorain county]. (Hay, '96)

42. Texas.

1. [Guadalupe R.], Victoria [Victoria county]. (F., '98.)
2. [Brazos R.], Brazoria [Brazoria county]. (F., '98.)

Faxon ('84 and '85) says: "The types of this species were dug out of burrows in solid blue clay in Detroit, Mich., by Mr. H. G. Hubbard, in August, 1873. The burrows were three to five feet deep. At the bottom of each burrow was a pocket in a layer of loose gravel and clay, holding water. Just above the water-line an enlargement in the burrow formed a shelf on which the animal rested."

Faxon ('90), in reporting this species from the lowlands bordering on the Wabash river, Clark county, Illinois, says: "According to the manuscript label accompanying these speci-

mens, they were found in burrows from eighteen inches to two feet in depth, containing from six inches to one foot of water. At the mouth of these burrows were mud chimneys five inches high. The soil was blue clay mixed with sand and gravel."

According to Hay ('96), *C. argillicola*, like its near relative *C. diogenes*, is a burrower and builds mud chimneys over its burrows. He took females with young as early as April 2.

Cambarus barbatus LeC.[14]

1. Alabama.

1. Escambia river, at Flomaton, above Pensacola [Escambia county]. (F., '90.)

9. Georgia.

1. Georgia. (F., '85.)

23. Mississippi.

?1. Eastern Mississippi. (F., '85.)

39. South Carolina.

?1. [Atlantic O.], Charleston. (F., '85.)

Cambarus bartonii Fabr.

Lake Superior. (F., '85.)

Canada.

?1. [St. Lawrence R.], Montreal, P. Q. (F., '85.)
2. [St. John R.], St. John, N. B. (F., '85.)
3. St. John river, just above Grand Falls, N. B. (F., '90.)
4. Abundant in valley of St. John, N. B. (Ganong, '98.)
5. Restigouche river, N. B. (Ganong, '98.)
6. Upsalquitch river, N. B. (Ganong, '98.)
7. Micomichi river, N. B. (Ganong, '98.)

7. District of Columbia.

1. Rock creek, Georgetown. (F., '85.)
2. [Potomac R.], above Washington. (F., '85.)

9. Georgia.

?1. Hagen states that he has seen specimens from Georgia. (F., '85.)

12. Indiana.

1. [White R.], Fall creek, Indianapolis, and Irvington, Marion county. (Hay, '96.)
2. [White R. or east fork of White R.], Bloomington, Clear creek, and May's cave, Monroe county. (Hay, '96.)
3. [Ohio R.], New Albany [Floyd county]. (Hay, '96.)
4. [East fork of White R.], Down's cave, and Connelly's cave, Lawrence county. (Hay, '96.)
5. [East fork of White R.], cave near Paoli, Orange county. (Hay, '96.)

14. *C. barbatus* was proposed by Faxon ('90) to replace *C. penicillatus* LeC., a preoccupied name.

16. Kentucky.

1. [Clinch R.], Cumberland Gap, Josh Bell county. (F., '85.)
2. Smoky creek, Carter county. (F. '85.)
3. Kentucky river, Little Hickman, Jessamine county. (F., '85.)
4. [——— R.], Hickman's Landing [——— county]. (F. '85.)
5. Bear creek, Grayson springs, Grayson county. (F., '85.)
6. [Green R.], Mammoth cave, Edmonson county. (F., '85.)
7. [Cumberland R.], Albany, Clinton county. (F., '98.)

18. Maine.

1. Head of Kennebec river, outlet of Moosehead lake [Somerset county]. (F., '90.)
2. [Kennebec R.], Madison, Somerset county. (F., '85.)
3. [Trib. St. John R.], Hamilton and Maysville, Aroostook county. (F., '85.)

?4. Moosehead lake and Solon, in the Kennebec valley. (F., '85.)

?5. Lobster pond and Patten, in the Penobscot valley. (F., '85.)

?6. Heron lake and Churchill lake, on Allegash river, a tributary of the St. John. (F., '85.)

19. Maryland.

1. [Potomac R.], Cumberland, Alleghany county. (F., '85.)
2. [Youghiougheny R.], Garret county. (F., '85.)
3. [Trib. Potomac R.], Washington county. (F., '85.)
4. [Trib. Potomac R.], Frederick county. (F., '85.)
5. [Potomac R.], Montgomery county. (F., '85.)
6. [Susquehanna R. or Chesapeake bay], Hartford county. (F., '85.)
7. [Patuxent R.], Howard county. (F., '85.)
8. [Potomac R.], Montgomery county. (F., '85.)

20. Massachusetts.

1. [Blackstone R.], North Grafton, Worcester county. (F., '85.)
2. [Hoosac R.], Williamstown, Berkshire county. (F., '85.)
3. [Hoosac R.], North Adams, Berkshire county. (F., '98.)

?4. Tributary of Housatonic river, Berkshire county. (F., '90.)

24. Missouri.

?1. Osage river. (F., '85.)

29. New Jersey.

1. [Delaware R.], Trenton [Mercer county]. (F., '85.)
2. [Trib. Delaware R. or Raritan R.], Schooley's Mountain [——county]. (F., '85.)
3. [Passiac R.], Orange [Essex county]. (F., '85.)

31. New York.

1. Lake Champlain [Clinton or Essex county]. (F., '85.)
2. [Trib. St. Lawrence R.], Ellenburg, Clinton county. (F., '85.)
3. [Trib. Hudson R.], Westport and Elizabethtown, Essex county. (F., '85.)
4. Fulton lakes, Hamilton and Herkimer counties. (F., 85.)
5. [La Grasse R.], Canton, St. Lawrence county. (F., '85.)
6. [Delaware R.], Port Jervis and Newburgh, Orange county. (F., '85.)
7. [Hudson R.], Fishkill, Duchess county. (F., '85.)
8. [Delaware R.], Fallsburg, Sullivan county. (F., '85.)
9. [Trib. Susquehanna R.], Sherburne, Chenango county. (F., '85.)
10. [Oneida lake], Cazenovia, Madison county. (F., '85.)

11. [Cayuga lake], Ithaca, Tompkins county. (F., '85.)
12. [Trib. Susquehanna R.], Berkshire, Tioga county. (F., '85.)
13. Genesee river, Rochester, Monroe county. (F., '85.)
14. [Niagara R.], Niagara, Niagara county. (F., '85.)
15. [Lake Erie], Forestville, Chautauqua county. (F., '85.)

32. North Carolina.

1. [Big Pigeon R.], Waynesville, Haywood county. (F., '98.)
2. [Trib. French Broad R.], Roan mountain, from an altitude of 6000 feet [Mitchell county]. (F., '98.)
3. Swannanoa river, Black mountain [Bumcombe county]. (F., '90.)
4. Newman's Fork, Blue Ridge, McDowell county. (F., '85.)
5. [Neuse R.], Kinston [Lenoir county]. (F., '85.)
6. [Trib. Holston R., or south fork New R.], Watauga county. (Moore, '93.)

34. Ohio.

1. [Ohio R.], Marietta [Washington county]. (F., '85.)
2. [Ohio R.], Cincinnati [Hamilton county]. (F., '85.)
3. [Trib. Ohio R.], Yellow Springs [Greene county]. (F., '85.)
4. Scioto river, Columbus [Franklin county]. (F., '85.)
5. [Ohio R.], Warren county. (F., '98.)

37. Pennsylvania.

1. [Trib. Ohio R.], Westmoreland county. (F. '98.)
2. [Juniata R.], Bedford and Pattanville, Bedford county. (F. '85.)
3. [Susquehanna R.], Windham, Bradford county. (F. '85.)
4. [Trib. Susquehanna R.], Hummelstown, Dauphin county. (F., '85.)
5. [Trib. Susquehanna R.], Carlisle, Cumberland county. (F., '85.)
6. [Susquehana R.], Berwick, Columbia county. (F., '85.)
7. Schuylkill river, near Philadelphia [Philadelphia county]. (F., '85.)
8. [Trib. Delaware R.], Chester county. (F., '85.)
9. [Susquehanna R.], Bainbridge, Lancaster county. (F., '85.)
10. [Alleghany R.], McKean county. (F., '85.)
11. [Alleghany R.], Foxburg, Clarion county. (F., '85.)
12. In springs and small brooks, rarely in large streams, Allegheny county. (Williamson, '01.)
13. [Delaware R.], Philadelphia, Montgomery county. (Moore, '93.)
14. [Delaware R.], Delaware county. (Moore, '93.)

38. Rhode Island.

?1. Pawcatuck river, near the border of Connecticut, Westerly [Washington county]. (F. '85.)

39. South Carolina.

?1. [Atlantic O.], Charleston [Charleston county]. (F., '85.)

41. Tennessee.

1. [Tennessee R.], Lineville cave, near Blountsville, Sullivan county. (F., '85.)
2. Doe river, Carter county. (F., '85.)
3. [Tennessee R.], Knoxville, Knox county. (F., '85.)
4. [Clinch R.], Claiborne county. (F., '98.)
5. [Trib. Tennessee R.], Monroe county. (F., '98.)
6. [Trib. Tennessee R.], McMinn county. (F., '98.)

44. Vermont.

1. [Lake Champlain], Burlington, Colchester, and Shelburne, Chittenden county. (F., '85.)

45. Virginia.

1. Peak creek, Pulaski [Pulaski county]. (F., '90.)
2. Shenandoah river, Waynesborough [Augusta county]. (F., '90.)
3. Holston river, Smyth county. (F., '85.)
4. Reed creek, west of Wytheville, Wythe county. (F., '85.)
5. [Trib. James R.], Bath county. (F., '85.)
6. [Trib. Chowan R.], Lunenberg, Lunenberg county. (F., '85.)
7. Tributaries of James river, Rockbridge county. (F., '85)
8. James river. (F. '85.)
9. Tributaries of Rappahannock river, Stafford county. (F., '85.)
10. [Potomac R.], Alexandria county. (F., '85.)
11. [Blackwater R.], Franklin, Southampton county. (F., '85.)
12. [Shenandoah R.], Clark county. (F., '85.)

47. West Virginia.

1. Branch of Clinch river, northern base of Clinch mountains [——— county]. (F., '85.)
2. [Trib. Kanawha R.], near White Sulphur Springs, Greenbrier county. (F., '85.)
3. [Trib. Ohio R.], Petroleum, Ritchie county. (F., '85.)
4. Patterson's creek [Mineral county]. (F., '85.)
5. Glade creek [Randolph or Tucker county?] (F., '85.)
6. South branch of Potomac river. (F., '85.)
7. [Patterson's creek], Williamsport, Grant county. (F., '85.)

Cambarus bartonii longirostris Fax.

1. Alabama.

1. Will's creek, Pollard, Escambia county. (F., '98.)

41. Tennessee.

1. [Clinch R.], Cumberland Gap [Claiborne county]. (F., '98.)
2. [Holston R.], Blountville [Sullivan county]. (F., '98.)

47. West Virginia.

1. Clinch river. (F., '98.)

Cambarus bartonii robustus Gir.

Canada.

1. Humber river and Don river, Toronto, P. O. (F., '85.)
2. Indian creek, Weston, P. O. (F., '85.)

11. Illinois.

1. [Sangamon R.], Decatur, Macon county. (F., '85.)

19. Maryland.

1. [Potomac R.], Montgomery county. (F., '85.)

31. New York.

1. [Lake Erie] Forestville, Chautauqua county. (F., '85.)
2. Genesee river, Rochester, Monroe county. (F., '85.)
3. [Lake Ontario] Sodus, Wayne county. (F., '85.)
4. Tributaries of Racket river, near Tupper's lake, St. Lawrence county. (F., '85.)
5. [St. Lawrence R.], Natural Bridge, Jefferson county. (F., '85.)
6. Fulton lakes, Hamilton and Herkimer counties. (F., '85.)
7. Oneida creek, Peterboro, Madison county. (F., '98.)
8. [Grass R.], Canton, St. Lawrence county. (F., '98.)

37. Pennsylvania.

1. Squaw run which empties into the Alleghany river about a mile and a half above Aspinwall, Allegheny county. (Williamson, '01.)

41. Tennessee.

?1. Doubtfully reported by Faxon ('85).

45. Virginia.

1. [Rappahannock R.], Fredericksburg, Spottsylvania county. (F., '85.)
2. [Trib. Kanawha R.], Wytheville, Wythe county. (F., '90.)

Gould ('41) reports this as an inhabitant of mountain streams, etc.

Godman ('42) describes the process of removing a small pebble which he had pushed into the small, irregular hole in the bed of a small brook: "He had thrust his broad, lobster-like claws under the stone, and then drawn them near to his mouth, thus making a kind of shelf; and, as he reached the edge of the hole, he suddenly extended his claws and ejected the encumbrance from the lower side, or down stream."

De Kay ('44) reports it as exceedingly common in the mountain streams of New York and the adjoining states, and as nocturnal in habits, hiding during the day under stones.

Erichson ('46) says: "Sehr haufig in Nordamerika in Bächen."

Abbott ('73) found this the one burrowing species of the region around Trenton, N. J., occurring in deep meadow ditches with muddy banks, in the banks of small streams, and occasionally in the river bank a little below the usual water-level.

According to Faxon ('85), *C. bartonii* is not a preeminently burrowing species like its relative, *C. diogenes*, but prefers the cooler water of the uplands, being found more commonly in clear streams and springs, while the clay bottoms and marshes are inhabited by *C. diogenes*. He reports young specimens

from a spring in Clark county, Virginia, the temperature of which is 67° F. He refers to the association with the cave forms, which has been noticed by various writers. Sloan (Faxon '85) reports this species as found in ponds and still water at New Albany, Ind., *C. sloanii* being the common form in running streams.

Hay ('96) also calls attention to the association with *C. pellucidus*, and says the largest and best-developed specimens he has ever taken came from the limestone caves of southern Indiana. It is to be looked for, however, in almost any spring or stream of clear running water, where it hides under stones or digs short burrows into the banks.

Schufeldt ('96) describes and figures a chimney of *C. bartonii robustus* found near the edge of a small stream in Montgomery county, Maryland, as about nine inches in height, very smooth inside, and with the pellets distinctly individualized outside. Many of the pellets were piled up at the base, and forty-two of them had rolled out beyond it. At a depth of fifteen inches water was reached in the burrow, and it was followed twenty-seven inches further, when it passed between two large stones, rendering further examination impossible.

Williamson ('01) states that in Allegheny county, Pennsylvania, *C. bartonii* is the most common species, being found in springs and smaller brooks, but rarely in larger streams.

Cambarus blandingii Har.

9. Georgia.

1. [Savannah R.], Richmond county. (F., '85.)
2. [Savannah R.], Savannah [Chatham county]. (Lonnberg, '98.)

19. Maryland.

1. [Patapsco R.], Baltimore county. (F., 85.)
2. [Choptank R.], Caroline county. (F., 85.)
3. [Choptank R.], Dorchester county. (F., '85.)
4. [Tribs. Potomac or Patuxent R.], St. Mary's county. (F., '85.)
5. [Chesapeake bay], Somerset county. (F., '85.)
6. [Wicomico or Pocomoke R.], Wicomico county. (F., '85.)
7. In a ditch near Ocean City [Atlantic O.], Worcester county. (F., '85.)

22. Mississippi.

1. [——— R.], Root pond [——— county]. (F., '85.)

29. New Jersey.

1. [Passaic R.], Essex county. (F., '85.)
2. Delaware river and tributaries, near Trenton [Mercer county]. (F., '85.)

51. New York.

1. [——— R.] (F., '85.)

32. North Carolina.

1. [Pamlico R.], Tarboro [Edgecombe county]. (F., '85.)
2. Tributaries of Neuse river, Goldsboro [Wayne county]. (F., '85.)
3. [Neuse R.], Kinston [Lenoir county]. (F., '85.)
4. [Atlantic O.], Beaufort [Carteret county]. (F., '85.)
5. Salmon creek [——— county]. (F., '85.)
6. [Cape Fear R.], Wilmington [New Hanover county]. (F., '85.)
7. Tar river, Rocky Mount [Edgecombe county]. (F., '90.)
8. Neuse river, Raleigh [Wake county]. (F., '90.)

39. South Carolina.

1. [Wateree R.], Camden [Kershaw county]. (F., '85.)
2. Saluda river. (F., '85.)
3. [Congaree R.], Columbia [Richland county]. (F., '85.)

42. Texas.

? [Trinity R.], Dallas [Dallas county]. (F., '85.)

45. Virginia.

1. James river. (F., '85.)
2. [Trib. Chowan R.], Lunenberg [Lunenberg county]. (F., '85.)
3. North river, Lexington [Rockbridge county]. (F., '90.)
4. Dismal swamp, outlet of Lake Drummond, Suffolk [Norfolk county]. (F., '90.)

Cambarus blandingii acutus.

1. Alabama.

1. [Mobile bay], Mobile [Mobile county]. (F., '85.)
2. [Trib. Black Warrior R.], Blount Spring, Blount county. (F., '85.)
3. [Trib. Black Warrior R.], Cullman, Cullman county. (F., '85.)
4. [Tennessee R.], Decatur, Morgan county. [F., '85.)
5. In pond formed by overflow of Tennessee river, Bridgeport, Jackson county. (F., '85.)

2. Arkansas.

1. [White R.], Batesville [Independence county]. (F., '98.)
2. [Trib. Black R.], Mammoth Springs [Fulton county]. (F., '98.)
3. [Washita or Ouachita R.], Camden [Ouachita county]. (F., '85.)

11. Illinois.

1. [Illinois R.], Athens, Menard county. (F., '85.)
2. [Illinois R.], Decatur, Macon county. (F., '85.)
3. [Illinois R.], Pekin, Tazewell county. (F., '85.)
4. [Trib. Illinois R.], Normal, McLean county. (F., '85.)

5. [Mississippi R.], Oquawka, Henderson county. (F., '85.)
6. [Illinois R.], Peoria, Peoria county. (F., '85.)
7. [Illinois R.], Lawn Ridge, Marshall county. (F., '85.)
8. [Lake Michigan], Evanston, Cook county. (F., '85.)
9. [Wabash R.], York, Clark county. (F., '90.)

12. Indiana.

1. [Trib. Wabash R.], Vincennes, Knox county. (Hay, '96.)
2. [Trib. White R. or Wabash R.], Wheatland, Knox county. (Hay, '96.)
3. [Tippecanoe R.?], Turkey lake, Kosciusko county. (Hay, '96.)
4. [Kankakee R.?], Lake Maxinkuckee, Marshall county. (Hay, '96.)
5. Kankakee river, Lake county. (Hay, '96.)
6. [Wabash R.], Terre Haute, Vigo county. (Hay, '96.)

13. Indian Territory.

1. [Trib. Kiamichi R.], Good Land [or Goodland], [Choctaw N.] (F., '98.)
2. [Walnut creek], Kainister [Chickasaw N.] (F., '98.)
3. [Trib. Saines creek], McAlester [Choctaw N.] (F., '98.)

14. Iowa.

1. [Iowa R.], West Liberty [Muscatine county]. (F., '85.)
2. [Mississippi R.], Dubuque [Dubuque county]. (F., '85.)

17. Louisiana.

1. [Mississippi R.], New Orleans [Orleans county]. (F., '85.)
2. Tangipahoa river, Amite City [Tangipahoa county]. (F., '85.)
3. [Tangipahoa R.], Tickfaw [Tangipahoa county]. (F., '85.)

23. Mississippi.

1. Tributary of Tombigbee river, Kemper county. (F., '85.)
2. [Trib. Mississippi R.], near Vicksburg [Warren county]. (F., '85.)

24. Missouri.

1. [Mississippi R.], St. Louis [St. Louis county]. (F., '85.)

32. North Carolina.

1. [Atlantic O.], Beaufort [Carteret county]. (F., '85.)

34. Ohio.

1. Portage river, at Oak Harbor [Ottawa county]. (F., '98.)

39. South Carolina.

1. [Atlantic O.], Charleston [Charleston county]. (F., '85.)

41. Tennessee.

1. [Mississippi R.], Memphis [Shelby county]. (F., '85.)

42. Texas.

1. [Red R.], Arthur [Lamar county]. (F., '98.)
2. [Gulf of Mex.], Corpus Christi [Nueces county]. (F., '98.)

48. Wisconsin.

1. [Lake Michigan], Racine [Racine county]. (F., '85.)
2. [Wisconsin R.], Sauk City [Sauk county]. (F., '85.)

Harlan ('30) says: "Inhabits the Southern states, where it is common in the marshes and rivulets."

Erichson ('46) says: "In den südlichen Staaten von Nordamerika, haufig in Sumpfen und Bächen."

Abbott ('73) found *C. acutus* frequenting running streams in the neighborhood of Trenton, N. J., having masses of vegetation upon which the animal rested, usually near the surface of the water. They were always observed with the head directed down stream. When disturbed, they darted backward down to the roots, apparently of the same plant upon which they were resting; after about ten minutes they would creep up the plant to their former resting-place. Abbott characterizes this as "a plant-loving species."

Smith ('74) reviews Abbott ('73) on this species.

Bundy ('82) says: "It [*C. blandingii acuta* (48.2) *fide* Faxon '85] occurs also in marsh ditches near Sauk City in company with *C. obesus*."

According to Faxon ('85), Mr. P. R. Uhler finds that this species belongs to the lowlands at the mouth of sluggish rivers, or near the ocean in muddy and grassy ditches and drains, and even in salt water, in company with *C. uhleri*. He has specimens from near Ocean City, Worcester county, Maryland [19.7], found in a ditch in holes six to nine inches deep. At Goldsborough, N. C., the same gentleman found it abundant in drains and branches running through cotton-fields, tributaries of the Neuse river [32.2]. The two females from Texas, which agree well with *C. blandingii* (42 ?), are labeled "burrowing crabs.

Lonnberg ('98) says: "The late Capt. C. Eckman, at Savannah, Ga., collected *Cambarus* (*blandingii*) in the hollow trunk of a fallen tree, two English miles from any open water."

See, also, *C. affinis*, *C. uhleri* and Faxon ('85), under *C. pellucidus*.

Cambarus carinatus Fax.

Mexico.

1. [—— R.], Guadalajara. (F., '98.)
2. [—— R.], Ameca, Jalisco. (F., '98.)
3. [—— R.], Hacienda de Villahuato, Michoacan. (F., '98.)

The altitude of Guadalajara is 5200 feet. (F., '98.)

Cambarus carolinus Erichs.[15]

13. Indian Territory.

1. [Trib. Arkansas R.], "Among the Cherokees." (F., 90.)

32. North Carolina.

1. [Tar R.], near Greenville [Pitt county]. (F., 85.)

37. Pennsylvania.

1. [Ohio, Alleghany or Monongahela R.], Shenley Park, Fern Hollow, and from a spring in Moon township, Allegheny county. (Williamson, '01.)

41. Tennessee.

1. [Clinch R.], Cumberland Gap [Claiborne county]. (F., 85.)

45. Virginia.

1. [Trib. Tennessee R.], Pennington's Gap, Lee county. (F., 85.)

47. West Virginia.

1. [Cheat R.], Cranberry Summit, Preston county. (F., '85.)

A species reported from the widely separated localities of northeastern Indian Territory, Allegheny county, Pennsylvania, and the remote Appalachian mountain region of Virginia and West Virginia.

According to Mr. Uhler (Faxon, '84 and '85), this species in the Appalachian region makes mud chimneys, like *C. diogenes*, which it seems to represent in the mountain regions, *C. diogenes* belonging to the lowlands.

Williamson ('01) has studied the habits of *C. dubius* Fax. in Allegheny county, Pennsylvania, where it is represented by a local variety. The chimneys of *C. diogenes* are usually constructed more neatly than those of *C. dubius*, while the burrows of *C. dubius* are usually more intricate In both species the burrows of younger animals are usually small tunnels, ending in a pocket, placed at such a depth that it is filled with water. September 24, one burrow, typical of a large individual of *C. dubius*, contained an adult female and forty-seven young, ranging from three-fourths to one and one-eighth inches in length. The chimney, about three inches high, broad and flattened, was not composed of compact pellets, as is usually the case with *C. diogenes*, and was sealed at the top. The burrow, circular, about one and one-half inches in diameter, and with smooth sides, ran

15. All the localities except North Carolina are for *C. dubius* Fax., the name *C. carolinus* Erichs. being used in view of the recent paper of Hay ('02).

in a slightly oblique direction, with two or three turns, to a depth of about fourteen inches, where it ended in a pocket, with a capacity of over a pint, half filled with water, in which the animals were found. From the main shaft extended a number of passages. One of these branched, one branch ending in a low, closed chimney at the surface, while the other ended about an inch below the surface. The remaining side tunnels, one of which branched, ended in pockets, the capacity of one of which exceeded a quart. The entrance and exit to the pockets was by the same tunnel. That they were not the accidental result of a deepening of the tunnel, on account of the lowering of the water, but were constructed for some purpose, was shown by their size and form, and by the fact that in many cases the entrance was from below, as would not be the case were they the result of changes in the depth of the tunnel. At some places in Fern Hollow the ground was honeycombed with burrows, and it was sometimes possible to show that the tunnels of several chimneys were connected. In habits the animals are nocturnal, specimens being found in the traps set for small mammals.

Cambarus chaplanus Fax.

Mexico.

1. Lake Chapala, state of Jalisco. (F., '98.)

Cambarus clarkii Gir.

1. Alabama.

1. [Mobile bay], Mobile [Mobile county]. (F., '85.)

8. Florida.

1. Three miles below Horse Landing, St. Johns river [——— county]. (F., '85.)
2. [Pensacola bay], Pensacola [Escambia county]. (F., '85.)

17. Louisiana.

1. Tangipahoa river [Tangipahoa county]. (F., '85.)
2. [Mississippi R.], New Orleans [Orleans county]. (F., '85.)

23. Mississippi.

1. [Gulf of Mexico], Ocean Springs, Jackson county. (F., '85.)

34. Ohio.

?1. [Rocky R.], Olmstead (?) [Cuyahoga county]. (F., '85.)

42. Texas.

1. Clear creek, Waller county. (F., '85.)
2. [San Antonio R.], San Antonio [Bexar county]. (F., '85.)
3. Between San Antonio and El Paso del Norte. (F., '85.)
4. Las Moras creek, Kinney county. (F., '98.)

According to Faxon ('85), this is the species commonly on sale in the New Orleans markets.

Cambarus clypeatus Hay.

23. Mississippi.

1. Bay St. Louis [Hancock or Harrison county]. (Hay, '99.)

Cambarus compressus Fax.

1. Alabama.

1. Second creek, Waterloo, and Cypress creek, Lauderdale county. (F., '85.)

Cambarus cornutus Fax.

16. Kentucky.

1. Green river, near the Mammoth cave [Edmonson county]. (F., '85.)

Cambarus cubensis Erichs.

Cuba.

1. In creeks in a little town opposite Havana. (F., '85.)
2. Stagnant ponds in Cuba (*fide* Saussure, *C. consobrinus*). (F., '85.)

Cambarus difficilis Fax.

2. Arkansas.

1. [Trib. Illinois R.], Prairie Grove, Washington county. (F., '98.)

13. Indian Territory.

1. [Trib. Gaines creek], McAlester [Choctaw N.] (F., '98.)

Reported from tributaries of the Arkansas river.

Cambarus digueti Bouv.

Mexico.

1. Affluents of the Rio Santiago, state of Jalisco. (Bouvier, '97.)

Cambarus diogenes Gir.

2. Arkansas.

1. [Trib. Illinois R. or White R.], Fayetteville, Washington county. (F., '98.)
2. [Trib. St. Francis R.], Paragould, Greene county. (F., '98.)

5. Colorado.

1. [——— R.], Clear lake [——— county]. (F., '85.)
2. [St. Vrain R.], near Boulder [Boulder county]. (Harris, '00.)

7. District of Columbia.

1. [Potomac R.], near Washington. (F., '85.)

11. Illinois.

1. [Trib. Illinois R.], Lawn Ridge [Marshall county]. (F., '85.)
2. [Lake Michigan], Evanston [Cook county]. (F., '85.)
3. [Trib. Mississippi R.], Bellville [St. Clair county]. (F., '85.)
4. [Trib. Illinois R.], Decatur [Macon county]. (F., '85.)
5. [Spoon R.], Abingdon [Knox county]. (F., '85.)
6. [Lake Michigan], Chicago [Cook county]. (F., '85.)

12. Indiana.

1. Long lake, Kendallville, Noble county. (F., '85.)
2. [Trib. White R.], Mechanicsburg, Henry county. (F., '85.)
3. [Wabash R.], Knox county. (F., '85.)
4. [Trib. White R.], North Salem, Hendricks county. (Hay, '96.)
5. [White R.], Irvington, Marion county. (Hay, '96.)
6. Kankakee river, Riverside [——— county]. (F., '90.)
7. [Trib. Wabash R.], Kokomo [Howard county]. (F., '90.)

14. Iowa.

1. [Mississippi R.], Davenport [Scott county]. (F., '85.)
2. [Iowa R.], Belmond, Wright county. (F., '98.)
3. Spring creek, at Delhi, Delaware county. (F., '98.)

15. Kansas.

1. [Missouri R.], Leavenworth [Leavenworth county]. (F., '85.)
2. Kansas river, Lawrence, Douglas county. (Harris, '00.)

16. Kentucky.

?1. [Ohio R.], near Louisville [Jefferson county]. (F., '85.)
?2. Mill branch, near Bee Spring, Edmonson county. (F., '85.)

19. Maryland.

1. [Patapsco R.], Baltimore county. (F., '85.)
2. [Chesapeake bay or Potomac R.], St. Mary county. (F., '85.)
3. [Choptank R.], Caroline county. (F., '85.)
4. [Chesapeake bay], Dorchester county. (F., '85.)
5. [Assateague bay or Pocomoke R.], Worcester county. (F., '85.)
6. [Youghiougheny R.], Deer Park, Garrett county. (F., '85.)

21. Michigan.

1. [Lake St. Clair], Detroit [Wayne county]. (F., '85.)

22. Minnesota.

1. Minnesota river, at Fort Snelling [Hennepin county]. (F., '98.)

23. Mississippi.

1. [Pearl R.], Monticello, Lawrence county. (F., '85.)

24. Missouri.

1. [Mississippi R.], St. Louis [St. Louis county]. (F., '85.)
2. [Missouri R.], Carroll county. (F., '85.)

29. New Jersey.

1. [Delaware R.], Mercer county. (F., '85.)

32. North Carolina.

1. [Cape Fear R.], Wilmington [New Hanover county]. (F., '85.)
2. [Neuse R.], Kinston [Lenoir county]. (F., '85.)
?3. [Atlantic O.], Beaufort [Carteret county]. (F., '85.)

34. Ohio.

1. [Scioto R.], Columbus and Lockbourne, Franklin county. (F., '98.)
2. [Trib. Miami R.], around Oxford [Butler county]. (Hargitt, '90.)

37. Pennsylvania.

1. [Trib. Alleghany R.], Derry station, Westmoreland county. (F., '85.)
2. Ohio or Alleghany river, Fern Hollow, Pittsburgh, Allegheny county. (Williamson, '01.)

41. Tennessee.

?1. Mud chimneys resembling those of *C. diogenes* are found. (F., '85.)

45. Virginia.

1. [Potomac R.], Alexandria county. (F., '85.)
2. [Atlantic O.], Accomack county. (F., '85.)
3. [Atlantic O.], Northampton county. (F., '85.)
4. [Rappahannock R.], Fredericksburg [Spottsylvania county]. (F., '85.)
5. [Trib. James R.], Petersburg [Dinwiddie county]. (F., '85.)
6. [Potomac R.], Prince William county. (F., '90.)

48. Wisconsin.

1. Tributaries of Pecatonica river, Green county. (F., '85.)
2. [Fox R.], Appleton [Outagamie county]. (F., '85.)
3. [Lake Michigan], Racine [Racine county]. (F., 85.)

49. Wyoming.

1. [Trib. South Platte R.], Cheyenne [Laramie county]. (F., 85.)

Cambarus diogenes ludoviciana Fax.

17. Louisiana.

1. [Mississippi R.], New Orleans [Orleans county]. (F., '85.)

Audubon ('39) figures the chimney of a crayfish, probably *C. diogenes*. In describing the food habits of the white ibis, he says: "The crayfish often burrows to a depth of three or four feet in dry weather, for, before it can be comfortable, it must reach the water. This is generally the case during the prolonged heats of summer, at which time the white ibis is much pushed for food. The bird, to procure the crayfish, walks with remarkable care towards the mounds of mud which the latter throws up while forming its hole, and breaks up the upper part

of the fabric, dropping the fragments into the deep cavity that has been made by the animal. Then the ibis retires a single step and patiently waits the result. The crayfish, encumbered by the load of earth, instantly sets to work anew, and at last reaches the entrance to its burrow; but the moment it comes in sight the ibis seizes it with its bill."

Girard ('52), whose observations were made in the meadows in the vicinity of Washington, published quite extensive notes on the habits of this species. The substance of his observations is given below, quotations being freely used where condensation seemed inadvisable.

Of the burrows, he says: "The holes, as they appear at the surface of the ground, are nearly circular, from seven-tenths of an inch to one inch and one inch and a half in diameter. The depth of the burrows varies according to the locations; this we generally found to be from sixteen inches to two feet, and sometimes three feet and more. The construction of the burrow itself is often exceedingly simple; from the surface of the ground the excavation exhibits a gradual slope in direction, more or less undulating for a distance of from five to ten inches, when it becomes vertical for six or eight inches, and then terminates in a sudden, bottle-shaped enlargement, in which the animal is found, the bottom of the burrow having no subterranean communication, no other issue except towards the surface; it is entirely isolated from its neighbers, and leaves no chance for escape to its inhabitant. The same burrow may have several external holes connected with it, several inclined channels, which, however, meet at a depth where it becomes vertical. We found constantly the cavity full of water, but this was in March and April; the bottom, for several inches, was filled with soft and pulpy mud."

"There are other instances of burrows somewhat more complex. Their direction may be oblique throughout their whole extent, and composed of a series of chambers or ovoid enlargements, succeeding each other at short intervals sometimes, also, and, connected with one of the chambers, a narrow and nearly vertical tubuliform channel extends downward to a much greater depth, and appears to us as a retreat, either during the cold winters or else during the dryness of the summer, when the water is low. That it is not for the mere purpose of

escaping pursuit, we infer from the fact that we repeatedly caught the animals in the chambers above, where they remain quietly instead of attempting to disappear into the apartments below."

He generally found a single male or female in a burrow, the latter, in March or April, carrying eggs. Sometimes, when very numerous, the windings of the upper part of the burrows would accidentally meet; each individual, however, seemed to remain in its own apartment.

A male and a female were found in one of the burrows. He was inclined to believe that the male goes in search of the female, since one was found "walking over the surface of the ground."

"In the spring, and, we are told, in the fall also, the burrowing crawfish builds over the holes of its burrow a chimney of the maximum height of one foot, but most generally lower. This chimney is circularly pyramidal in shape, is constructed of lumps of mud varying in size, irregularly rolled up one upon another, and intimately cemented together. Its exterior has a rough and irregular appearance, whilst the interior is smooth and as uniform as the subterraneous channel, having the same diameter as the latter. The cementing of the successive balls of mud is easily accounted for when we bear in mind that the latter are brought up in a very soft state, and that their drainage and subsequent solidification, on their exposure to the atmospheric air and rays of the sun, is all that is required to unite these parts."

As to the actual method of working he made no observations, except that the work was performed at night, and that the finding of the imprint of the second and third pairs of claws indicated that after the parcels of mud had been brought to the surface—probably "embraced between the chest and large claws, as suggested by Godman" ('60)—they were arranged and fixed in definite place by means of these organs.

"The closing of the aperture," he concluded, "is accomplished by bringing up several pellets of mud, depositing them temporarily on the edge of the chimney, and then drawing them back into close contiguity."

"The number of chimneys, distributed without regularity, in one particular locality, is often very great. We have seen localities where the holes could be traced from the edge of the

rivulets to the middle of the meadows; still, there being no subterraneous communication from one burrow to another, the animal, at any rate, would have to crawl out of the water and walk over land. Colonies of burrowing crayfish are found, we are told, in the interior of lands, far away from any rivulets of water, a circumstance which would lead to the supposition that these at least pass their entire lives in such localities, instead of spending one season in the water and another in dry lands. . . . For we learn from Mr. T. R. Peale, of Washington, that chimneys of mud, in all points similar to those just described, were observed by him in New Grenada, along the Rio Magdalena, several hundred miles from the seashore, and consequently indicating the presence of a species of crawfish which we do not hesitate in pronouncing distinct from *C. diogenes*."

According to Bundy ('77), a female of *C. obesus*, caught at the mouth of a tile ditch at Mechanicsburg, Ind., on New Year's day, 1876, had her abdominal appendages loaded with eggs nearly ready to hatch.

Bundy ('82 and '83) gives *C. obesus* as one of the largest and most abundant and preeminently the burrowing species of the region, *C. gracilis* having, according to Doctor Hay, the same habit. Unlike most other species, it prefers stagnant water, frequenting ponds and meadow ditches, often wandering far from bodies of water and burrowing in wet fields and swales. One burrow was followed twelve feet without reaching the end.

Tarr ('84) studied the habits of *C. diogenes* at the head of a small stream on the Virginia side of the Potomac, a few miles above Washington, in May, 1883. Many of his observations confirm those of Girard ('52), with whose work he was not improbably unacquainted, since he makes no references at all to other writers, while some are slightly different. As to the locality: "It was between two hills, at an elevation of 100 feet above the Potomac, and about a mile from the river. Here I saw many clayey mounds covering burrows scattered over the ground irregularly, both upon the banks of the stream and in the adjacent meadows, even so far as ten yards from the brook."

The variation in depth of the burrows mentioned by Girard ('52) seems to be explained by Tarr, who observed that at that time of the year the stream was receding and the meadow was beginning to dry, while not a month previous the meadow, at

least as far back as the burrows were found, had been covered with water. The burrows near the stream were less than six inches in depth, and there was a gradual increase in depth as the distance from the stream became greater. The holes farther from the stream were in nearly every case covered by a mound which, when they were far distant from the stream, was hard and dry, while those nearer had only a very small chimney, or none at all, and subsequent visits proved that at that time of the year the mounds were just being constructed. In the deeper holes, some of which reached a depth of three feet, he invariably found at various points enlargements which, he considers, represent the end of the burrow at some earlier period, the burrow being undoubtedly projected deeper as the water falls in the ground, for all burrows went down to water.

"The burrows near the stream were seldom more than six inches deep, being nearly perpendicular, with an enlargement at the base, and always with at least one oblique opening."

Tarr's description of the burrows corresponds well with that given by Girard. He also gives a diagram of a section of a typical burrow. "Occasionally the burrows are very tortuous, and there are often two or three extra openings, each sometimes covered by a mound." The burrows have a diameter of one and one-half to two inches, are smooth and of almost uniform diameter for the entire length.

Of the chimneys he says: "There is every conceivable shape and size in the chimneys, ranging from a mere ridge of mud, evidently the first foundation, to those with a breadth of one-half the height. . . . The mounds were usually of yellow clay, although in one place the ground was of fine gravel, and there the chimneys were of the same character. They were always circularly pyramidal in shape, the whole inside being very smooth, but the outside was formed of irregular nodules of clay, hardened in the sun, and lying just as they fell when dropped from the top of the mound. A small quantity of grass and leaves was mixed throughout the mound, but this was apparently accidental." In no case did he find the burrows connected. "Both males and females have burrows, but they were never found together, each burrow having but a single individual."

Tarr's explanation of the presence of an extra oblique opening is as follows: He thinks that the crayfish retire to the

streams in winter and construct their burrows in the spring for the purpose of rearing their young and escaping the summer droughts. He says: "I found one burrow which, on my first visit, was but six inches deep, and later had been projected to a depth of at least twice as great, and the inhabitant was an old female." He concludes that while the marsh is still covered with water after the winter has passed impregnation takes place and the burrows are immediately begun. At first the direction is oblique, and so long as the mouth is covered with water this is satisfactory, but upon the receding of the water a perpendicular burrow becomes more economical and this direction is maintained with more or less regularity, the perpendicular opening to the surface representing a shorter route for conveying the mud from the deeper excavation, the height of the mound over the vertical shaft depending upon the depth of the latter.

"About the middle of May the eggs hatch, and for a time the young cling to the mother. . . . After hatching, they must grow rapidly, and soon the burrow will be too small for them to live in, and they must migrate."

Tarr considered that the chimney was not "a necessary part of the nest," but only the mud brought up in digging. He carried away several chimneys, and no attempt was made to replace them but in one case, where, after removing the chimney, he partially filled the hole with mud, there was a simple half-rim of dried mud when the place was again visited, indicating that the burrow had been cleared soon after the first visit.

He says: "There is seldom more than a pint of water in each hole, and this is muddy and hardly suitable to sustain life. . . . How these animals can live for months in the muddy, impure water is to me a puzzle. They are very sluggish, possessing none of the quick motions of their allied *C. bartonii*, for, when taken out and placed either in water or on the ground, they move slowly. The power of throwing off their claws when grasped is often exercised."

Tarr leaves as a question the method of securing food. Evidently they do not "tunnel" for roots. "Food must be secured at night or when the sun was not shining brightly. In the spring and fall the tender stalks of meadow grasses would

furnish food, but when these become parched and dry, they must either dig after and eat the roots, or search in the stream."

Abbott ('84) does not agree with Tarr's ('84) conclusion that the "chimney" is simply the rejected material, but thinks that it is the product of design on the part of the animal, which "often studies the localities with care, and builds to suit the chosen site." His reasons for the conclusion are that on the sloping side of a ditch, where, had the material been simply rejected, it would have rolled down the bank, artistic towers two inches in diameter and from eight to eleven inches in height were erected. "In several instances the base of the tower was especially prepared for by having the ground leveled and smoothed before the foundation masses of *puddled* clay were put in position. Of a series of forty towers built by the *Cambarus diogenes* that I observed on the banks of a ditch, not one could have been the result of accident, as suggested by Mr. Tarr."

"The towers that were found in meadows at a considerable distance from open water were invariably broader at the base and never so high as those described on the edge of flowing water. These open-meadow towers or chimneys, however, were all found to be composed of pellets of clay so arranged as to render it highly improbable that their positions were fortuitous. Indeed, in the majority of instances it would have been practicable to have rolled the little balls of clay to a considerable distance from the opening of the tunnel."

Mr. Abbott suggests that the fact that some of the most elaborate structures are the result of the work of half-grown or even smaller crayfish may have a bearing on the question of design in "tower" building. "Some of the most slender and tallest were the work of diminutive little fellows, who certainly could have avoided a deal of labor if the chimneys or towers were not designed."

Abbott ('85) gives the results of the observations of his nephew, Mr. Jos. De B. Abbott, who, by the aid of a candle, observed the crayfish building his "chimney." According to him, the crayfish was seen to partially emerge from its burrow, bearing "on the back of its right claw a ball of clay mud which, by a dextrous tilt of the claw, was placed on the rim of the chimney. Then the crayfish remained perfectly still for a few

seconds, when it suddenly doubled up and dropped to the bottom of its burrow. There elapsed some three or four minutes between each appearance; but every time it came it brought a ball of clay and deposited it in the manner I have described. About two-fifths of the balls were not placed with sufficient care, and rolled down the outside of the chimney."

He believes that the closing of the orifice of the chimney is merely the result of the accidental falling in of pellets from the rim. In some localities where the burrowing crayfish abounds, there is a weather proverb to the effect that, when the crayfish closes the opening of his chimney in dry weather, there will be a rainfall within twenty-four hours.

Faxon ('85) characterizes *C. diogenes* as "preeminently a burrowing species, being found in meadows and clay bottoms, often at a great distance from any permanent stream." He quotes much of Girard ('52), and reviews Tarr ('84), and Abbott ('84), and states that he has been informed by Mr. P. R. Uhler that during the period of incubation the female goes into pools, ditches and quiet waters along the margin of overflowing creeks. He reviews Abbott ('85).

Holder ('86) discusses some habits of the crayfish, unfortunately omitting the name of the species. It was, however, probably *C. diogenes* or *C. gracilis*.

His observations were made in northern Illinois. Here he saw patches, sometimes several acres in extent, almost completely covered with small mounds eight to twelve inches high and six to twelve inches in diameter, flat on top, and nearly always grassed over the entire surface. So close were they that he could walk for considerable distance by stepping from one to the other.

He noticed that in these places the greatest number of mounds were usually close to a sluggish stream or low, damp place, radiating up the slope from here, the most distant heaps being perhaps 200 feet away. The animals were discovered by digging.

On the bank of a small river that flows through the prairie north of Freeport, he found numerous "heaps" formed in the black, clay mud, about four or five feet above the water-level. Nearly every one of these contained a crayfish living in water that "must have come from above," since the holes had no

connection with the river. The animals were generally found out of the water, just within the hole, and upon being alarmed would drop down. Having no chance to escape, "they were quite savage."

He believes that too much water is "disagreeable" to the animal, and that the "mounds," above and away from the streams, are the result of an attempt of the animal to obtain a location where he can safely remain in or out of the water. Since crawling out on an open bank would expose them to many dangers, they burrow in the saturated soil, "and at times penetrating from the stream bed." An opening is usually left on the side or at the top. The "mounds," he concludes, are usually built when the streams rise, the animals leaving the swift current and taking to higher ground for safety.

Mr. Holder was informed by a gentleman residing in Freeport that not many months before heavy rains had so greatly increased the volume of the little river that many quite large trees were almost submerged. When the water was at its height it was noticed that above water the trunks were completely covered with crayfish, which crawled up out of the water by hundreds, covering every available space.

He states that in certain portions of the Western country the work of the crayfish often greatly increases the difficulty of breaking up new land. Some farmers, however, consider that they enrich the land by keeping it open and in many other ways, and that land with the "crayfish heaps" is worth more per acre from this cause.

Hargett ('90) gives observations on the crayfish in the region around Oxford, Ohio. He mentions *C. gracilis* and *C. obesus*, and his observations probably apply, for the most part at least, to these species, although some may apply to a third form. He found them abounding in the streams of the adjacent country, where they might be observed at any time during at least eight months of the year, leaving the winter quarters at first sight of spring, and returning only with freezing weather in the autumn.

According to him, the best time for taking the "larger species of *Cambarus*, such as *gracilis*, *obesus*, etc.," was just at the spring thaw, especially during the usually accompanying period of large rainfall, when they "venture boldly forth" from their hibernating places "in the banks and fields adjoining sluggish

streams" . . . "for the purpose of foraging, seeking new quarters, or more probably mating."

He refers to the question raised by Chaney ('89) about the feeding habits of the crayfish, and states that it will take living prey, as earthworms. In aquaria, they devoured in large quantities growing algæ and pondweed.

During the several weeks he kept in aquaria specimens of *C. obesus* and *C. gracilis* taken immediately upon "their first issuance from the state of hibernation," upon the breaking up of the severe winter of 1888; several pairs were noticed in copulation.

He never found them mating except in early spring, March and April, and sometimes in May, which is also the season of ovipositing. In only two instances was he able to get reports of females in "berry" at a later period than June; and in each case but a single specimen was found. "I have frequently found large males traveling considerable distance overland in the month of March to neighboring streams and ponds, doubtless in response to the sexual instinct, which is remarkably dominant at that time. In many cases the boldness with which such journeys were prosecuted in open daylight proved a fatal adventure, the daring subject falling a victim to the rapacity of the ubiquitous crow."

He had frequently taken specimens which had recently exuviated, and this was invariably in the spring, chiefly in May and early June. He also noticed perfect casts, which could not remain in such perfect condition during the winter, very commonly in the creeks in the spring and early summer.

Schufeldt ('96) observed the burrows of crayfish, probably *C. diogenes*, in southern Louisiana, especially in the vicinity of New Orleans. Some of his observations agree with those of Girard and Tarr, neither of whose writings he mentions. On a low plain south of New Orleans, he observed a great number of "chimneys" irregularly scattered over the entire meadow, but becoming markedly more numerous as one approached either side of a ditch. Some were short and flattened out; others reached the height of one foot and were uniformly built. In some places they stood in couples, side by side, but were usually separated from each other by eight or ten paces. All were built vertically, even when they stood on the sloping bank

of the ditch. A number of the taller ones, but more usually the lower ones, had their tops sealed over. The "chimneys" were evidently built up of "small pellets of mud laid on in a single course, the fusing together of the pellets depending somewhat upon the dryness of the ground when the structures were erected."

Of a burrow of *C. diogenes* in the neighborhood of Washington, D. C., he says: "Right on the bank of the stream I opened another; it only passed down eleven inches, when it terminated in a chamber about as big as my two fists, and placed at the side. It was below the water-level, and contained a fine living specimen of *C. diogenes*."

The "sealing-in" of the burrow, he found, was very thorough, the top being as thick as the walls, inside passage terminating "in a smooth, concave, hemispherical end." How and why the crayfish seals its burrow, he says, is as yet unexplained. "Possibly it may do this by backing up the burrow, and, by turning round and about, manipulate the moistened clay or mud into place by the use of its lateral tail fins and telson." As to the reason for sealing, he suggests that it may be that the orifice is sealed to prevent the upper rim from falling back into the burrow, to shut out rain or rising water, to prevent the attack of enemies, or while the parent is laying her eggs at the bottom of the burrow.

Schufeldt, like Tarr, believes that the chimney is not the result of design on the part of the animal, but is simply the most convenient and safe way of getting rid of the pellets.

Hay ('96), after giving some of the older observations, says: "The subterranean tunnels may sometimes be found to extend for several feet, and, as the animal frequently excavates them at some distance from water, they must reach a depth great enough to supply moisture sufficient for the need of the animal. During the dry months of the summer, however, they seem to lie in the end of their burrows in a sort of stupor. I have seen them fall from the end of an excavation, apparently lifeless, but capable of moving when put into water. In the early spring, when they come forth to breed, is the only season when they are a noticeable member of our fresh-water fauna. They move about chiefly at night, though I have frequently taken numbers of them from ditches and small streams on bright, sunny days.

Of a lot of thirty-five specimens collected on the evening of April 2, 1892, twenty-nine were males and six were females. At this date they were in copulation. Eggs were laid from April 18 to 30. I have frequently found females bearing well-grown young in small streams, and, therefore, do not think the habit of burrowing is adopted as a protection to the young generation, but rather to furnish a retreat during the dry summer months."

The portion of Schufeldt ('97) dealing with the crayfish is practically a reprint from his other paper ('96).

Harris ('00) reports the taking of a female with swimmerets loaded with eggs in a not very late stage of development May 3. Since, in an examination of the same ditch four days later, he found many burrows in the bank, but no adult individuals in the open water, he considered that there was an indication that the eggs pass through the most of the stages of their development in the burrow, as is certainly the case with *C. gracilis*. In reporting material from Boulder, Colo. (5.2), he quotes a part of a letter from Francis Ramaley, as follows: "We find crayfish here in ditches and ponds, much as in other localities, but as most of the ditches are dry part of the year, the animals are not abundant. Our streams are mostly swift-running, and crayfish are seldom found in them. I have not noticed the animals at high altitudes, but they may occur there, doubtless up to 8000 feet at any rate."

See, also, colors of *Cambarus*.

Cambarus dubius Fax.

See *C. carolinus* Erich.

Cambarus erichsonianus Fax.

1. Alabama.

1. Big Cahawba river [Bibb, Perry or Dallas county]. (F. '98).

41. Tennessee.

1. Rip Roaring fork, five miles northwest of Greeneville [Greene county]. (F., '98.)
2. Estanaula creek, Athens [McMinn county]. (F., '98.)
3. Matlock Spring creek, near Athens [McMinn county]. (F., '98.)

Central Alabama and southeastern Tennessee, in tributaries of the Alabama and Tennessee rivers.

Cambarus evermanni Fax.

1. Alabama.

1. Escambia river at Flomaton, above Pensacola [Escambia county]. (F., '90.)

Cambarus extraneus Hag.

1. Alabama.

1. Big Cahawba river [Bibb, Perry or Dallas county]. (F., '98.)

9. Georgia.

1. Etowah river, Rome [Floyd county]. (F., '85.)

41. Tennessee.

1. Tennessee river, near the border of Georgia [——— county]. (F., '85.)

Cambarus extraneus girardianus Fax.

1. Alabama.

1. Cypress creek, Lauderdale county. (F., '85.)

41. Tennessee.

1. Eastanaula creek, near Athens [McMinn county]. (F., '98.)

Cambarus fallax Hag.

8. Florida.

1. St. Johns river, at Jacksonville [Duval county], Hawkinsville [——— county], Orange Bluff [——— county], Horse Landing [——— county], Blue Spring [Lake county], and Lake Jessup [Orange county]. (F., '85.)
2. [St. Johns R.?], Magnolia [Magnolia Springs, Clay county?]. (F., '85.)
3. St. Johns river, Orange county. (Lonnberg, '94.)
4. Sulphur springs, at Lake Jessup, Orange county. (Lonnberg, '94.)
5. Lake Eola, Orange county. (Lonnberg, '94.)
6. Fern creek, Orlando, Orange county. (Lonnberg, '94.)
7. Indian river [Brevard county]. (F., '85.)
8. [Indian R.], Titusville, Brevard county. (F., '85.)
9. [Trib. St. Johns R.?], Eustis, Lake county. (F., '98.)
10. [Trib. Suwanee R.], Gainesville, Alachua county. (F., '98.)

A species confined to the St. Johns and Indian river systems, except for the three questionable localities, one of which (8.10) seems to be in the territory drained into the Gulf of Mexico instead of the Atlantic ocean.

Lonnberg ('94) says: "Of this I collected specimens in the sulphur springs at Lake Jessup and in St. Johns river, in Lake Eola, in Fern creek, at Orlando, Orange county [Fla.]"

Faxon ('85) says: "Specimens were collected in Blue spring, St. Johns river [Fla.], a mineral spring impregnated with sulphur and magnesia—temperature, 70 deg. F. They were clinging to the under side of leaves.

See, also, *C. alleni*.

Cambarus forceps Fax.

1. Alabama.

1. Cypress creek, Lauderdale county. (F., '85.)

41. Tennessee.

1. [Trib. Tennessee R.], Knoxville [Knox county]. (F., '85 and '90.)
2. Clinch river, at Walker's Ford, eleven miles northwest of Tazewell [Claiborne county]. (F., '98.)
3. Bull's (or Big Sycamore) creek, tributary of Clinch river, seven miles south of Tazewell [Claiborne county]. (F., '98.)

45. Virginia.

1. Middle fork of Holston river, Glade Spring [Washington county]. (F., '90.)

Cambarus girardianus Fax.

See *C. extraneus girardianus*.

Cambarus gracilis Bundy.

11. Illinois.

1. [Trib. of Illinois R.], along watercourses, in early spring, in the neighborhood of Normal [McLean county]. (F., '85.)
2. [South fork Sangamon R.], Athens [Menard county]. (F., '85.)
3. [Trib. Illinois R.], Lawn Ridge [Marshall county]. (F., '85.)
4. [Mill creek or Wabash R.], York [Clark county]. (F., '90.)
5. [Trib. Illinois R. or Lake Michigan], neighborhood of Chicago [Cook county]. (Hay, '96.)

12. Indiana.

?1. Hay ('96) thinks that there is no doubt that the species will be found in the prairie region in the western portion of the state.

14. Iowa.

1. [Mississippi R.], Davenport, Scott county. (F., '85.)

15. Kansas.

1. [Trib. Verdigris R. or Neosho R.], Labette county. (F., '90.)
2. [Trib. Kansas R.], Douglas county. Stagnant ponds in early spring, and burrows later in summer. (Harris, '00.)

24. Missouri.

1. Tributary Mississippi river. I have found the chelæ of crayfish, undoubtedly this species, around stagnant ponds in St. Louis, St. Louis county.
?2. [—— R.], Day Brook, Jasper county. (F., '98.)

34. Ohio.

1. [Trib. Miami R.], region around Oxford [Butler county]. (Hargitt, '90.)

48. Wisconsin.

1. [Lake Michigan or trib. Illinois R.], prairies near Racine [Racine county]. (F., '85.)

Bundy ('82) states that it is found abundantly along watercourses in early spring at Normal, Ill., and that Doctor Hay

found it burrowing in the low grounds on the prairies [at Racine, Wis.], emerging from its holes at nightfall and after rains.

Faxon ('85) states that according to Dr. P. R. Hay, *C. gracilis* burrows in the clay in the prairies near Racine, Wis., and that Professor Forbes reports it as common along the watercourses in early spring in the neighborhood of Normal, Ill.

Being a burrower, *C. gracilis* is one of the species that is hard to obtain, especially the males, and this probably accounts for the meager reports of its distribution.

Mr. H. Garman says (Faxon, '85) that he has examined hundreds of specimens taken along watercourses in the neighborhood of Normal, Ill., and has not found a dozen males.

Hay ('95) says: "It is a burrower, coming forth probably only during the breeding season in the early spring, when it inhabits the watercourses."

Harris ('01) notes its presence in shallow, stagnant ponds in the neighborhood of Lawrence, Kan., in company with *C. virilis* and *C. immunis*. These ponds are usually very muddy, and have usually, in the shallow parts, which are apt to become dry during the summer, a rank growth of *Polygonum* and plants of like habit.

Harris ('00) records material as very plentiful in these stagnant ponds in early spring, but never knew of material being taken in running creeks. In one pond, which was carefully watched, the females appeared March 13, while the males were not found until April 15, when one was secured, another being taken some days later at the top of its burrow in a pasture not far from the pond. In August two males and one female were taken from the mouths of their burrows in a yard some distance from a running stream, but where the ground was low and inclined to be somewhat moist. The animal does not seem to be entirely nocturnal in its habits, and is not infrequently found at the top of its burrow in the daytime. The lowlands in which this species lives are frequently flooded at times of great rainfall, in which case the animals leave their burrows, and upon the subsidence of the water may be found wandering over the surface of the ground. The females of the species are olive-green in color, the males almost a salmon-red. The writer had been told by people from various parts of the state (Kansas)

of the numbers of red crayfish seen after a heavy, washing rain, and was inclined to consider the species widely distributed.

He considers that individuals of this species must exuviate in their burrows, since the ponds in which the females are found in the early spring were very carefully watched without finding a specimen which was at all soft from exuviation. In the spring females were occasionally found in these ponds with *a few* young which were nearly old enough to leave the parent. This makes it seem altogether probable that those females without young have lost them before or immediately upon taking to the open water. In *C. immunis*, the females exuviate in the spring as soon as the young abandon them, but this would seem to indicate that such is not the case with *C. gracilis*.

In the fall of 1900 there were many young crayfishes which seemed to be *C. gracilis* in the ponds, about October 20 to November 20 appearing in great numbers about the same time that *C. immunis* disappears. Young of this species were also noticed early in the spring of 1900. These young crayfish, which were from three-fourths to seven-eighths of an inch in length when they disappeared in November, 1900, appeared again about the 1st of March, 1901. They were taken in great numbers. A few days later the ponds froze over, but the animals were still to be found, apparently as plentiful as ever, under a layer of ice about an inch thick. They grew rapidly, and by the 1st of May had attained a length of from one to nearly one and one-half inches.

Many smaller animals of five-eighths of an inch in length were found in the ponds and ditches on May 9, probably the young of *C. gracilis*, which were still carried by the females as late as March 27. In the spring of 1901 the adults did not appear until after the young.

He did not succeed in determining the date of copulation or laying of eggs. The eggs in the ovaries of females taken in this way were by no means fully developed.

This species, as compared with some others, *C. immunis* for instance, he considers shows a very small percentage of mutilation, it being very seldom that an individual is found with one of the great claws wanting, or showing any indications of having been regenerated.

Harris ('02) records the finding of an adult female in a stag-

nant pond near Lawrence, Kan., in August, 1901, the only time he had ever taken an adult specimen in open water during the summer.

The males of this species must spend considerably more of their time in the burrows than do the females, as has been shown by the observation of Garman and Harris, who have seen only three adult males, all first-form, the adult second-form male being as yet unknown.

See, also, Hargitt ('90), under *C. diogenes*, and Holder ('86), under *C. diogenes*.

Cambarus hagenianus Fax.[16]

39. South Carolina.

1. Seaboard of Charleston [Charleston county]. (F., '85.)

Cambarus hamulatus Cope and Pack.

41. Tennessee.

1. [——— county], Nickajack cave. (F., '85.)

See Faxon ('85), under *C. pellucidus*.

Cambarus harrisonii Fax.

24. Missouri.

1. [Trib. Meramec R.], Irondale [Washington county]. (F., '85.)

Cambarus hayi Fax.

23. Mississippi.

1. Noxubee river [or Oaknoxubee creek], Macoun [Noxubee county]. (F., '85.)
2. [Trib. Tombigbee R.], Artesia [Lowndes county]. (F., '89.)

Cambarus hylas Fax.

24. Missouri.

1. West fork of Black river, Reynolds county. (F., '90.)

Cambarus immunis Hag.

1. Alabama.

1. [Trib. Tennessee R.], Huntsville [Madison county]. (F., '85.)

11. Illinois.

1. [Mississippi R.], Oquawka [Henderson county]. (F., '85.)
2. [Trib. Mississippi R.], Bellville [St. Clair county]. (F. '85.)
3. [Trib. Illinois R.], Lawn Ridge [Marshall county]. (F., '85.)
4. [Trib. Illinois R.], Normal [McLean county]. (F., '85.)
5. [——— R.], Aux Plains [——— county]. (F., '85.)

16. The adoption of the name *C. hagenianus* Fax., proposed by Faxon ('85) for Hagen's material, in case it should prove to be specifically distinct from Erichson's *C. carolinus*, has been shown to be necessary by Hay ('02).

12. Indiana.

1. White river, Marion county. (Hay, '96.)
2. Fall creek, Marion county. (Hay, '96.)
3. [White R.], Irvington, Marion county. (Hay, '96.)
4. Long Lake, Kendallville, Noble county. (Hay, '96.)
5. Wabash river, Posey county. (Hay, '96.)
6. Twin Lakes, Marshall county. (Hay, '96.)
7. Wabash river, New Harmony [Posey county]. (F., '90.)
8. [Wabash R.], Lafayette [Tippecanoe county]. (F. '90.)

14. Iowa.

1. [Iowa R.], West Liberty, Muscatine county. (F., '85.)
2. [Des Moines R.], Ames, Story county. (F., '98.)
3. Cedar river, Cedar Rapids, Linn county. (F., '98.)
4. Mapleton river, Mapleton, Monona county. (F., '98.)
5. Bryer river, Arion, Crawford county. (F., '98.)
6. [Iowa R.], Belmond, Wright county. (F., '98.)

15. Kansas.

1. [Trib. Smoky Hill R.], Ellis [Ellis county]. (F., '85.)
2. [Missouri R.], Leavenworth [Leavenworth county]. (F., '85.)
3. [Kansas R.], in stagnant ponds, Douglas county. (Harris, '00.)
4. [Kansas R.], in stagnant ponds on the prairie near Onaga, Pottawatomie county. (Harris, '02.)

21. Michigan.

1. Detroit river, Detroit [Wayne county]. (F., '85.)

22. Minnesota.

1. [Trib. Mississippi R.], Richfield, Hennepin county. (F., '85.)

24. Missouri.

1. [Mississippi R.], St. Louis [St. Louis county]. (F., '85.)

26. Nebraska.

1. [Platte R.], South Bend, Cass county. (F., '98.)

31. New York.

1. Small stream flowing into Oneida lake [——— county]. (F., '98.)

34. Ohio.

1. [Lake Erie], Sandusky, Erie county. (F., '98.)
2. Northern Ohio, near shore of Lake Erie. (F., '98.)

48. Wisconsin.

1. [Lake Michigan], Milwaukee [Milwaukee county]. (F., '85.)

49. Wyoming.

1. [Laramie R.], near Laramie [Albany county]. (F., '98.)

Mexico.

1. [——— R.], Orizaba. (F., '98.)

Cambarus immunis spinirostris Fax.

12. Indiana.

1. Streams of Vigo county. (Hay, '96.)

15. Kansas.

1. Ward's creek, Shawnee county. (F., '85*b*.)
2. Stagnant ponds, Douglas county. (Harris, '00.)

41. Tennessee.

1. [Trib. Mississippi R.], Obion county. (F., '85.)

Harris ('02) summarizes most of the literature on the habits of this species and presents his own observations. *C. immunis* has been reported from muddy ponds in Michigan (Faxon, '85), Minnesota (Herrick, '82), Illinois (Forbes, '76), and Indiana (Hay, '96). The material he examined seemed quite variable, and a part of it probably belongs to Faxon's variety *spinirostris*. In Douglas county, Kansas, where his observations were made, *C. immunis* is the most common species, being found in roadside ditches and stagnant ponds, and is exceedingly abundant in stagnant ponds in an old river-bed. These ponds are from six to eighteen inches deep, depending upon the dryness of the season, are very muddy, and have usually around the edges a rank growth of *Polygonum* and plants of like habit. From such a pond, one day in October, 1898, were taken about 1500 specimens, of which only a few were less than two and one-half inches in length. There were not more than a half-dozen small specimens in the whole lot, but other collections were made which showed the animals in all stages of development. In some of the ponds *C. immunis* seemed to be the only species, but in others it was found associated in predominating numbers with *C. gracilis* and *C. virilis* (?), but these do not occur in such great numbers as does *C. immunis*. According to him, *C. immunis* is a burrowing and, at least to a certain extent, a chimney-building species.

Hay's ('96) suggestion as to the perishing of the crayfish upon the drying up of the ponds seems to be due to lack of opportunity for examining the ponds in different conditions, since in many places which were examined, in all stages of drying up, no considerable number of dead ones were found. In early September, 1900, a pond which earlier in the season had contained many crayfish was found to contain few crayfish, but had many burrows around the edge. One of these, having a chimney about four inches high and five inches in diameter at the base, fifteen inches deep, and an inch and a half in diameter, with a cistern-shaped chamber about three and one-half or four

inches across at the bottom, was found to contain in this chamber a large first-form male and a somewhat smaller female. The burrow had apparently been carefully sealed by the animals. Some time later the pond was again examined, and no crayfish were found, but numbers of chimneys in various stages of disintegration were seen. In another pond containing more water, the crayfish were very abundant at about the same time. About the middle of October the locality was again visited; some of the burrows had chimneys, others were simply open at the top—probably old burrows whose chimneys had been disintegrated by the weather. The form of the chimney varies greatly. Sometimes the mud appears to be just thrown out on one side, then, after a considerable amount of material has accumulated, the remainder is thrown out wherever convenient, forming an irregular circular mound one to three inches high and six to nine inches across; sometimes a long ridge with a shaft in the middle is formed, the material being thrown out in two directions; while again the work sometimes seems to be discontinued before so much mud is removed to make it inconvenient to throw it all to one side, thus forming a crescent-shaped pile.

The largest chimneys noticed were about five inches high and three inches in diameter at the top. These were sometimes much inclined from the perpendicular. He concludes that for this species the theory of Tarr ('84) and Schufeldt ('97), that the chimney is simply material ejected from the burrow and not the result of a design on the part of the animal, is correct. Chimneys in presumably the same sort of locality as those described by Abbott ('84) were examined, and he could not convince himself that anything other than the easiest method of disposing of material could have prompted the animal to build a chimney-like structure. The mud is brought up in such a moist condition that there would be little danger of the pellets rolling down, as suggested by Abbott ('84). The amount of mud brought up sometimes is very considerable, amounting, in some cases, to as much as 200 cubic inches. The accidental sealing of the burrow would seem impossible. The opening through the chimney seems to be left till the last, when it is filled from the top, or near the top, to almost the level of the ground, where the shaft has a concave, hemispherical end, which is not

so smooth as Schufeldt's ('97) description would seem to indicate. Prints of the chelæ in the mud were noticed. One case, at least, was noticed, in which the shaft was filled with clay to somewhat below the surface of the ground.[17] The shaft usually goes straight down, but in some cases may be somewhat sinuous. They are quite deep, one being followed down four feet without reaching the end. He was not able to convince himself of the presence of a ledge upon which the animal could rest, as stated by Hubbard (Faxon, '84 and '85), for *C. argillicola*, although in some cases the burrow seemed to be expanded in a way which might serve for this purpose.

One case was noticed in which a lateral shaft originated about six inches below the surface and ended somewhat higher, about eighteen inches from its connection with the main shaft. It might seem that the animals do not like to stay under water very long, since, when an excavation extending somewhat below the water was made in one of the burrows, the animal two or three times came out of the water and darted back before an attempt to catch him was finally successful. The burrow was left for a few minutes, and when again examined a medium-sized female had crawled out of the water and was standing on the almost perpendicular side of the excavation. The theory that the burrows are made to escape the dry months of summer seems to be the correct one for this species, while, of course, the purpose of the burrows made or enlarged upon the approach of winter is evident. It is certain that they are not adopted as retreats while the eggs are being hatched, for females were taken in the open ponds in the fall, apparently soon after the eggs were laid, and they came out early in the spring, about March 20, to complete the process of hatching the eggs.

Harris ('02) reports material from a stagnant pond on the prairie, near Onaga, Pottawatomie county, Kansas. The ponds had been in existence about six years and had never been known to go dry. They probably had no connection during high water with the nearest creek, which was about a quarter of a mile away. No fish had ever been found in the ponds, but specimens of *Amblystoma tigrinum* Green, which is sometimes found in the same localities as *C. immunis* in Douglas county, were found.

17. I have since found numbers of burrows of this or other species in which this is the case, clay of a very different nature from that of the chimney, and apparently coming from a different stratum, being used.

The material was taken April 1, 1902. Some of the females were carrying eggs, but none were noticed with young.

Herrick ('96) records a large number of females, taken from a pond in Ann Arbor, Mich., on the 16th of November, when the ice was just beginning to form, as already in berry.

Cambarus indianensis Hay.

12. Indiana.

1. Patoka river, Patoka, Gibson county. (Hay, '96.)
2. [Patoka R.], Huntingburg, Dubois county. (Hay, '96.)

Hay ('96) says: "Concerning the habits of this species, I have been able to ascertain nothing. It probably is a form which frequents open water, much after the fashion of its close relative, *C. affinis*, of the East, of which Doctor Faxon was at first inclined to regard this as a variety."

Cambarus jordani Fax.

9. Georgia.

1. Etowah river, near Rome [Floyd county]. (F., '85.)

Cambarus lancifer Hag.

2. Arkansas.

1. St. Francis river, at Greenway [Clay county] and Big Bay [——— county]. (F., '98.)

23. Mississippi.

1. Root pond [——— county]. (F., '85.)
2. [Trib. Pearl R.], Vicksburg [Warren county]. (F., '98.)

Cambarus latimanus Lec.

1. Alabama.

1. [Trib. Black Warrior R.], Blount Springs [Blount county], Cullman [Cullman county], and Sand Mountain. (F., '85.)
2. [Tennessee R.], near Bridgeport [Jackson county]. (F., '85.)
3. [Trib. Black Warrior or Tennessee R.], Attalla, Etowah county.

9. Georgia.

1. [Trib. Oconee R.], Athens [Clark county]. (F., '85.)
2. [Oconee R.], Milledgeville [Baldwin county]. (F., '85.)
3. [Chattahoochee R.], Roswell [Cobb county]. (F., '85.)

23. Mississippi.

1. [Gulf of Mexico], Ocean Springs [Jackson county]. (F., '85.)

39. South Carolina.

1. [Reedy creek], near Greenville [Greenville county]. (F., '85.)
2. [Congaree R.], near Columbia [Richland county]. F., '85.)

41. Tennessee.

1. [Cumberland R.], near Ashland City, Cheatham county. (F., '85.)

Faxon ('85) says: "Mrs. C. L. Herrick collected small specimens at Ocean Springs, Miss., on the Gulf of Mexico, which appear to be this species, but its favorite habitats are the higher regions at a distance from the coast."

Cambarus lecontei Hag.

1. Alabama.

1. [Mobile bay], Mobile [Mobile county]. (F., '85.)

9. Georgia.

1. [Trib. Oconee R.], Athens [Clark county]. (F., '85.)

Cambarus longidigitus Fax.

2. Arkansas.

1. White river, Oxford Bend [——— county]. (F., '98.)

Cambarus longulus Gir.

32. North Carolina.

1. Spring creek, Hot Springs [Madison county]. (F., '90.)

41. Tennessee.

1. Watuga river, Elizabethton [Carter county]. (F., '90.)
2. [Tennessee R.], Knoxville [Knox county]. (F., '90 and '98.)
3. [Clinch R.], Cumberland Gap, [Claiborne county]. (F., '98.)
4. [Trib. French Broad R.], Greeneville [Greene county]. (F., '98.)
5. [Clinch R.], Tazewell [Claiborne county]. (F., '98.)

45. Virginia.

1. [Shenandoah R.], Waynesborough [or Waynesboro], [Augusta county]. (F., '90.)
2. Lick Run, James river [——— county]. (F., '90.)
3. North river, Lexington [Rockbridge county]. (F., '90.)
3. [Trib. Kanawha river], Wytheville [Wythe county]. (F., '90.)
5. South fork of Holston river, near Marion [Smyth county]. (F. '90.)
?6. [Trib. James R.], Bath county. (F., '90.)

47. West Virginia.

?1. [Trib. Kanawha R.], near White Sulphur Springs [Greenbrier county]. F., '90.)

Cambarus maniculatus LeC.

9. Georgia.

1. LeConte ('56) says: "Habitat cum priori." [*A. fossorum* = *C. troglodytes.*]

Cambarus medius Fax.

24. Missouri.

1. [Trib. Meramec R.], Irondale [Washington county]. (F., '85.)

Cambarus meeki Fax.

2. Arkansas.

1. Walnut Fork, Piney [Johnson county]. (F., '98.)
2. [Trib. of Illinois or White R.], Fayetteville [Washington county]. (F., '98.)

Reported from tributaries of the Arkansas river.

Cambarus mexicanus Erichs.

Mexico.

1. [——— R.], Mirador [———]. (F., '85 and '98.)
2. [——— R.], Santa Maria [———]. (F., '98.)
?3. [——— R.], "Les ruisseaux du Mexique. Pris a Tomatlan, dans les Terres Chaudes." Saussure's locality for *A. aztecus*. (F., '85.)
?4. [——— R.], Pueblo. Locality for *A. aztecus*. (F., '85.)

Cambarus mississippiensis Fax.

23. Mississippi.

1. Eastern Mississippi. (F., '85.)
2. [Oaknoxubee creek], Macon [Noxubee county]. (F., '85.)

Cambarus montezumæ Saussure.

Mexico.

1. [——— R.], marshes of the valley of Mexico. (F., '85.)
2. [——— R.], Chapultapec. (F., '85.)
3. Lake Tezcoco, near city of Mexico. (F., '85.)
4. [———], Pueblo. (F., '85.)
5. Lake San Roque, Trapuato. (F., '85.)

According to Faxon ('85), Lake Tezcoco is said to be salt.

Cambarus montezumæ areolatus Fax.

Mexico.

1. [——— R.], Parras, Coahuila. (F., '85 and '98.)

Cambarus montezumæ dugesii Fax.

Mexico.

1. [———], State of Guanajuato. (F., '98.)

Cambarus montezumæ occidentalis Fax.

Mexico.

1. [———], Mazatlan. (F., '98.)

Bouvier ('97) says of *C. montezumæ:* "Elle est répresentée dans les envois de M. Diguet par le varieté *tridens* sous sa form la plus nette, et prouvient soit de Guanajuato où elle habite les eaux courantes, soit des envoirons de Guadalajara (état de Jalisco) ou elle fut trouvée en grande abondance dans la source de *l'agua azal*, au mileau des racines des naiadés."

Cambarus nais FAX.

15. Kansas.

1. [Verdigris or Neosho R.], Labette county. (F., '85 and '90.)
2. Small branch of Coal creek, Montgomery county. (Harris, '00.)

A species reported from the southwestern portion of Kansas, drained by the tributaries of the Arkansas river.

Harris ('00) reports this species from a rocky creek in southern Kansas—branch of Coal creek, Montgomery county. The creek winds between sandstone hills and is fed by many springs. It is of varying depths, being in some places eight or ten feet deep, while a short distance away it will be only a few inches. It sometimes goes dry in places, due, no doubt, to the failure of some of the springs that feed it.

Cambarus nebrascensis GIR.

26. Nebraska.

1. [——— R.], Fort Pierre [——— county]. Known only from the description of Girard ('52).

Cambarus neglectus FAX.

2. Arkansas.[18]

1. [White R. or trib.], Batesville, Independence county. [F., '98.)
2. [Trib. Illinois R. or White R], Fayetteville, Washington county. (F., '98.)
3. [Trib. Illinois R.], Prairie Grove, Washington county. (F., '98.)
4. Spring creek, Johnson [Washington county]. (F., '98.)

14. Iowa.

1. Turkey river, Fort Atkinson, Winneshiek county. (F., '98.)

15. Kansas.

1. Mill creek, Wabaunsee county. (F., '90.)
2. Republican river, near Guy, Cheyenne county. (F., '90.)
3. Sappa creek, Oberlin, Decatur county. (F., '90.)
4. Wildcat creek, about two miles west of Manhattan, Riley county. (Harris, '02.)

?5. See *C. virilis* 15, ?27.

24. Missouri.

1. Clear, rocky stream, about four miles northwest of Springfield, Greene county. (Harris, '02.)
2. Stream flowing from Galloway cave, Galloway, Greene county. (Harris, '02.)
3. James river, near Galloway, about eight miles southeast of Springfield, Greene county. (Harris, '02.)

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18. A. W. Purdue, department of geology, University of Arkansas, writes me: "The water of the streams of north Arkansas is usually clear at average stage, and, being supplied largely by springs, is, I should judge, much below the average temperature of streams in this latitude. The water is rather swift, and flows in many places over rock bottom, but of course there are places where the bottom is mud. I have noticed that the springs of north Arkansas, which are cold enough for pleasant draughts during the hot summer days, are filled with small crayfish. . . . Illinois and White rivers are never connected, even during the highest water."

4. James river, Springfield [Greene county]. (F., '98.)
5. [Trib. Neosho or Grand R.], Day Brook, Jasper county. (F., '98.)
6. [Hickory creek], Neosho, Newton county. (F., '98.)

42. Texas.

1. Red river, Arthur [Lamar county]. (F., '98.)

Harris ('02) made some observations on the habits of this species near Springfield, Greene county, Missouri, during the early part of June, 1901. (24, 1, 2, and 3.) In the James river, near Galloway, about eight miles southeast of Springfield, this was the only species observed, although probably not the only one occurring in the river. At this place the James river is a rather swiftly flowing stream, with rocky bed, quite shallow in the swiftly running places, and with rather high wooded hills along the sides.[19] Crayfish were quite abundant, being found under loose stones and resting in the strands of rich vegetation,[20] which stood almost horizontally in the swiftly running water. Around Boiling Springs, where one of the cool, subterranean rivers of the region breaks through the rocky bed of the stream, they were very plentiful.

In a clear, rocky stream, about four miles northwest of Springfield (24, 1) crayfish were found in abundance, the smaller and more numerous species being *C. neglectus*, and were very active, darting from stone to stone when disturbed, but usually remaining under cover but a short time. In the stream flowing from Galloway cave (24, 2) *C. neglectus* and *C. rusticus* were taken, the former being the more abundant, if not the only species found at the mouth of the cave, where it occurred in great abundance under the small, loose stones. Here the water has practically the same temperature as that within the cave, which is said to remain at 57 deg. F. winter and summer. The animals were very inactive, the cold water, apparently, numbing them to such an extent that it was not at all difficult to take them with the hand.[21] A little distance down the stream, where the water was warm, the animals were noticed to be as active as usual. A striking effect of the low temperature seems to be seen in the hatching of the eggs. Many of the

19. Broadhead ('74) says of the streams of southwestern Missouri: "Those flowing through the Lower Carboniferous rocks of the southwest are clear, full, and rapid, and afford a mighty water-power. Among them are Spring river, Centre creek, Shoal creek, James's Fork of White river, Wilson's creek, Finley creek, and the head streams flowing into the Sac river."

20. Probably *Fontinalis*.

21. The water here, he states, is probably not more than fifteen degrees above that in which Harris ('02) found *C. virilis* so numb as to be almost incapable of movement.

females taken at the mouth of the cave were carrying eggs or recently hatched young, while none of those taken in the other localities were found with young at all. He thought that he found young crayfish which had but recently left the female in the vegetation near Boiling Springs, in the James river.

The distribution of this species is very interesting. It is found in the territory drained by the Mississippi in Iowa, Missouri, Kansas, Arkansas, and Texas. In Iowa it is reported from the very northeastern part, from a stream emptying directly into the Mississippi. In Missouri it is reported from the southwestern part, in the territory drained by the James river, in Greene county (24—2, 3, 4), which passes almost directly south into the White river, which crosses Arkansas diagonally and empties into the Mississippi with the Arkansas. In the northern part of Greene county (24.1) the drainage is toward the northeast and into the Missouri river, by way of the Osage river. The most southwestern localities (5, 6) are drained into the Arkansas through the Neosho or Grand river in Kansas and Indian Territory. In Arkansas it is found in the White river (1) in the north-central part and in the northwest (2, 3, 4) in the territory drained into the Arkansas by the Illinois river a little east of the Osage. In Texas it is reported from one locality, the Red river. In Kansas, *C. neglectus* is quite closely confined to the Republican river valley, being found, however, towards the east in some of the immediate tributaries of the Kansas river.

The interest lies in the widely separated localities from which the species has been reported. The character of the streams of the Ozark mountains, from which this species has been most frequently recorded, is well known, and from the limited information at hand the Turkey river seems to have some characteristics in common with them. While in the main it seems to occur in the upper waters of streams there are exceptions to this rule, and some of the localities from which it has been reported show that it is not exclusively confined to characteristic mountain streams.[22]

22. Under *C. neglectus*, Harris ('02) says of the Republican river: "The Republican river, in Cheyenne county, wherever I have seen it, is a shallow stream, perhaps 50 to 100 feet wide, with a bed of loose sand. It sometimes, though rarely, goes dry in places so far as the surface is concerned, but it is said that water can always be found by digging a few inches into the sand of the river-bed." I know nothing of the character of Sappa creek, but Mill creek is said to be a muddy stream, with occasional rock riffles. The character of the Red river is known, but the material recorded from that place may have been washed down from the head waters of the streams where it is so abundant.

Cambarus obscurus Hag.

31. New York.

1. Genesee river, Rochester [Monroe county]. (F., '85.)

37. Pennsylvania.

1. [Alleghany or Youghioughany R.], Westmoreland county. (F., '98.)

Hagen ('70) thinks *C. obscurus* may be identical with *A. fossor* Raf. Rafinesque says of *A. fossor:* "It burrows in meadows and willows, which it perforates and damages."

Cambarus palmeri Fax.

2. Arkansas.

1. St. Francis river, at Greenway [Clay county], and Big Bay [——— county]. (F., '98.)
2. Black river, at Black Rock [Lawrence county]. (F., '98.)
3. [Trib. St. Francis R.], Paragould, Greene county. (F., '98.)

41. Tennessee.

1. A brook running into the eastern side of Red Foot lake, near Idlewild hotel, Obion county. (F., '85.)

Cambarus palmeri longimanus Fax.

13. Indian Territory.

1. [Trib. Kiamichi R.], Good Land [or Goodland], [Choctaw Nation]. (F., '98.)
2. Walnut creek, Kainister. (F., '98.)

42. Texas.

1. [Red R.], Arthur [Lamar county]. (F., '98.)

Reported from a limited territory in southern Indian Territory and northern Texas, the Red river (42.1) forming the boundary.

Cambarus pellucidus Tellk.

12. Indiana.

1. [——— R.], Shiloh cave, Down's cave, Dunnihue's cave, Lawrence county. (Hay, '96.)
2. [——— R.], cave at Clifty, Bartholomew county. (Hay, '96.)
3. [——— R.], cave near Paoli, and in Lost river, Orange county. (Hay, '96.)
4. [——— R.], Wyandotte cave, Wildcat cave, small cave near Wyandotte, and Marengo cave (?), Crawford county. (Hay, '96.)
5. [——— R.], caves in Harrison county. (Hay, '96.)
6. [——— R.], caves near Madison, Jefferson county. (Hay, '96.)

16. Kentucky.

1. [——— R.], Mammoth cave and other caves in Edmonson county. (F., '85.)

Cambarus pellucidus testii Hay.

12. Indiana.

1. [——— R.], Mayfield's and Truett's caves, Monroe county. (Hay, '96.)

The type of *Orconectis inermis* Cope was taken by Cope ('72 and '72*b*) from a pool in a cool, "lively" stream in a subterranean channel to which he had gained access by descending a well about twenty feet deep, in the neighborhood of the cave.

On May 5, several of the specimens of *C. pellucidus* taken in the Mammoth cave in November by Putnam ('75), and taken to Massachusetts, were still in good condition, although they had eaten very little since their capture, taking "only a few mouthfuls" of the bits of cooked meat, raw liver and bread crumbs given them. Putnam ('75) says: "The specimens of *Cambarus bartonii*, the eyed crayfish collected in the cave at the same time, on the contrary, are quite ready to eat, and at once seize any food offered to them. The difference in the action of the two species at such times is quite striking. The moment the water in the jar is disturbed, the eyed species rears itself upon its tail, thrown out its large claws, seizes the piece of meat or bread, and, hastily conveying it to its mouth, generally holds onto the morsel until it is all eaten, though this species will sometimes take but a bite or two and then drop the food, and I do not think it will touch the same piece again."

"The blind species, on the contrary, darts backward as soon as the food is dropped into the water, and then extends its antennæ and stands as if on the alert for danger. After a long while, sometimes from fifteen to thirty minutes, it will cautiously crawl about the jar with its antennæ extended, as if using them for the purpose of ascertaining danger ahead. On approaching the piece of meat, and *before touching it*, the animal gives a powerful backward jump and remains quiet for awhile. It then approaches again, and sometimes will go through this performance three or four times before it concludes to touch the article, and when it does touch it the result is another backward jump. After another quiet time, it again approaches, perhaps only to jump back once more, but when it finally concludes that it is safe to continue in the vicinity of the meat, it feels with its antennæ for awhile, and then takes the morsel in its claws and conveys it to its mouth. I have twice seen the meat dropped as it was passed along the base of the antennæ, as if the sense of smell, or more delicate organs of touch seated at that point, were again the cause of alarming the animal. When the jaws once begin to work, the piece of

meat or bread, if very small, is devoured, but if a little too large only a few bites are taken and the food is dropped and not again touched, though the animal crawls over it and rests upon it without being in the least concerned. These actions are best noticed by feeding with raw liver and by not disturbing the crayfish for some days before. . . . If food is often presented, the crayfish, becoming accustomed to the disturbance and probably to the smell, pays no attention to it."

A female slightly less than two and one-half inches in length, taken in the cave November 13, "was perfect in all respects except the right large claw, which was represented by a rudimentary one, entirely useless to the animal, and so small as to be almost imperceptible." From November 14 to 24, in fighting with others in the same jar, she "lost the larger part of her antennæ, the third, fourth and fifth legs from the left side, the fifth from the right side, and two end joints of the third leg on the right side." On January 28 or 29 "she cast her shell, and came forth with a soft white covering, which was nearly two weeks in hardening. Then all of the legs or claws that were perfect before were of the same size, but in addition the great claw of the right side was developed to about one-half or two-thirds the size of its fellow, and was apparently of as much use. The two missing joints of the third leg on the right side were also developed, though not quite to their full proportions. The fifth leg on the right side and the third, fourth and fifth on the left side were now reproduced, but in a small and rudimentary manner; all the joints were present, but every part was reduced in size. The antennæ were reproduced about two-thirds their full size."

During the month of February the tips of the antennæ were accidentally broken, so as to reduce their length about one-third.

"April 20. The old shell is cast whole, as before, and with her new dress the crayfish has all her legs and claws nearly perfect. The great claw at the right side is now very nearly as large as that of the left. The tip of the third leg of the same side is fully perfected, and all the legs that were rudimentary before are now developed, apparently to their full proportionate size, with the exception of the last on the right side, which is not quite perfect, the two terminal joints being somewhat ru-

dimentary. The antennæ are reproduced, well formed, and of about their full length, though the one on the left side is not quite as long as the other."

"From these observations it will be seen that the parts, such as the legs and antennæ, are not reproduced in perfection on one shedding of the shell, but each time the shell is cast they are more nearly perfect than before, and that in this instance it has taken three moltings, one before the animal was captured, to bring the great claw nearly to its full size, and one more molting, at least, will be necessary in order to perfect this important member. The posterior legs, on the contrary, are perfected in two moltings, and in this case in about five months from the time they were lost. The antennæ are developed more rapidly and approach their full size in one molting, and reproduce lost portions in less than three months. Since its capture the animal has not increased perceptibly in size. . . ."

It will be noticed that the specimen exuviated two times within three months. "This milk-white specimen of *C. pellucidus* has not changed color after shedding its shell twice and living in the full light of day, and often for hours in the sunshine, for over five months. Between the two exuviations it fed not more than three or four times, and then upon only a small quantity of food."

In conclusion he says: "It is also interesting to record that extremes of temperature do not effect these crayfish from the cave, as my several specimens have several times been retained in a heated room, and again have been exposed for weeks to such intense cold as to freeze the water in their jars."

In a foot-note added at the time of going to press, nearly ten months after the specimens were taken, he says: "Another specimen of the blind species, of about the same size, is still alive, and has been exposed to full light of day since last November, has eaten but very little, and has not shed its shell. The small specimen of *C. bartonii* mentioned above as having molted [about February 20] has not increased in size nor changed in color since February, and is apparently in good condition."

In reference to the change of color upon exuviation, he found that "the young specimen of *C. bartonii* had the same color after shedding as before," and that the theory that the grayish

specimens of *C. pellucidus* are those which have recently shed their skins will not hold good, since his specimen of *C. pellucidus* was milk-white, both before and after shedding.

Shaler ('75) concludes, from the association of *C. pellucidus* and *C. bartonii*, and the light color which often characterizes cave forms of the latter, that the blind species is derived from the present outside form, with which it is connected by transitions, and supposes that the cave fauna is reenforced by interbreeding with that of the outside!

In connection with the study of the habits of the cave forms, it is of interest to note that Leydig finds that the external flagellum of the antennule, on which are located the cones to which he has ascribed an olfactory function, is composed of thirty-six segments. The cones are, for the most part, confined to the middle third of the flagellum, where there are seven to each segment, the number decreasing toward either end. He was unable to compare other species of *Cambarus*, but Wright ('84) follows out the suggested comparison, using *C. propinquus*, and finds that the external branch of the antennule is composed of eighteen or nineteen segments, of which the distal nine alone bear olfactory cones, and only five of them, the eleventh to the fifteenth, have the full number of eight on each joint. From this he concludes that *C. pellucidus* forms no exception to the conclusions which had been reached concerning the greater development of olfactory organs in cave-inhabiting species than in those with well-developed eyes.

Faxon ('85) discusses these results, but finds that in *C. propinquus* the number of segments in the external flagellum may be as high as thirty-five, and of these fifteen or sixteen may carry olfactory organs. In *C. affinis* as many as thirty-three segments are counted, and nineteen of these are provided with olfactory setæ, while a moderate-sized *C. blandingii* from New Jersey shows about fifty segments, twenty-nine of which are provided with setæ. It thus seems that Wright's conclusions are not supported by the facts. He calls attention to the interesting fact that in *C. pellucidus* the olfactory setæ are better developed than in most species of *Cambarus*. In the specimen of *C. hamulatus* examined he finds thirty segments in the outer flagellum, and the olfactory setæ are long, as in *C. pellucidus*.

Faxon ('85), finding a small specimen in a jar containing *C. putnami* from Green river, near the Mammoth cave, concludes that the blind species sometimes finds it way out of the cave.

During the summers of 1891 and 1892, Hay ('93) made observations on the blind crayfishes of southern Indiana. Material was collected in Monroe, Lawrence and Orange counties. Between the localities visited in Monroe and Lawrence counties no material was obtained, owing to the heavy autumn rains, which had so muddied the subterranean streams as to obscure everything in them. In Shiloh cave, Lawrence county, he found them very common. He says: "The cave is a capacious one, and is traversed by a good-sized stream which will average a foot in depth. The bottom is of gravel, and full of small stones, which have fallen from the ceiling. A few crayfish were found here, but it was in a small branch running into the large stream about an eighth of a mile from the entrance of the cave that they were most abundant. The bottom of the branch is composed almost entirely of an exceedingly fine clay, with here and there a large rock that affords a ready resting-place for the animals."

"When first observed, the crayfish were generally, I might almost say always, resting quietly in some shallow part of the stream on one of the banks of clay. They lay with all their legs extended and their long antennæ gently moving to and fro. Once or twice I saw them on the shore a foot, at least, from the water, and one of these appeared to have been digging in the soft mud. When in the water I found it almost impossible to catch them with the net, and, after a few trials, threw it aside as useless. A much surer method was to approach them slowly with the hand and then suddenly seize them. When once touched they started off in great haste for some protecting rock, but often in their alarm would dart out on the bank, where they would lie, unable to get back to the water. They did not appear to be at all sensitive to the light. I have often tried the experiment of slowly passing my candle back and forth a few inches above them, or of suddenly removing the light and then bringing it close again, but with no effect whatever."

"Noise has no effect; a loud call or a shrill whistle they do

not notice, nor does disturbing the water seem to affect them, and it is only when they are touched that they manifest fear."

"The larger of these crayfishes could inflict a pretty severe nip with their pincers, but they did not appear to be as strong in this regard as the outside species."

Material from Mayfield's cave, Monroe county, Hay makes the types of a new subspecies, *C. pellucidus testii*.

Cambarus penicillatus LeC.

See *C. barbatus* Fax.

Cambarus pilosus HAY.

15. Kansas.

1. [Solomon R. or trib.], Beloit, Mitchell county. (Hay, '99.)
?2. Trib. Salt creek, Russell county. (Harris, '00 and '02.)

So far reported only from the north-central portion of Kansas.

Harris ('00) gives the following notes on the habits of specimens which he refers, with a little hesitation, to this species. "He [Mr. Sutton, who collected the material] found them July 14, burrowing under tussocks of grass on the edge of a small stream in Russell county, Kansas. A first-form male and a female were usually found in each burrow, both taking part in the work of excavation. The whole burrow was under water, running back at first horizontally, then sometimes downward at various angles. The burrows examined ranged from fifteen to to twenty-four inches in length, and were somewhat enlarged and sometimes branched at the end.

"In burrowing, the mass of mud was pushed out in front of the animal, being held between the anterior end of the animal and the chelæ, which were held with the inner margins close together, while the meros was held well up and close to the body, thus forming a sort of prismatic or pyramidal-shaped space between the chelæ and the anterior end of the thorax. Mr. Sutton was firmly convinced that the mass of mud was held between the chelæ and the body to prevent the mass from going to pieces while being moved along in the water, since when a stone was to be removed it was simply pushed along in front of the chelæ.

"As was stated above, the whole burrow was made under water, and no attempt was made to construct anything like a 'chimney' out of the mud removed. This was simply pushed

out of the mouth of the burrow, thus forming a 'dump' such as is frequently seen at the mouth of hillside coal-mines.

"The crayfish which build the regular 'chimneys' usually burrow at night, but these specimens were actively at work at noon, when they were taken."

It is interesting to note that the method which Mr. Sutton observed *C. pilosus* use in removing a stone from its burrow is essentially the same as that described nearly sixty years before for *C. bartonii* (?) by Godman ('42).

Harris ('02) adds that Mr. Sutton's material was taken in Kelp Fork, a "wet weather" stream of fresh water which flows into Salt creek, a tributary of the Saline river. At the time the material was taken water was not flowing from the pools into the creek. During the summer of 1901, Mr. Sutton took material from a well about five feet in depth, near the above region. The water from the pools, when high, would overflow into the wells.

Cambarus propinquus Gir.

Lake Superior. (F., '85.)

Canada.

1. [St. Lawrence R.], Montreal [Quebec]. (F., '85).
2. [Lake Ontario], Toronto [Ontario]. (F., '85.)

11. Illinois.

1. [Rock R.], Freeport, Stephenson county. (F., '85.)
2. [Rock R.], Ogle county. (F., '85.)
3. [Illinois R.], Geneva, Kane county. (F., '85.)
4. [Branch of Illinois R.], Pekin, Tazewell county. (F., '85.)
5. [Trib. Illinois R.], Normal, McLean county. (F., '85.)
6. [Trib. Illinois R.], Decatur, Macon county. (F., '85.)
7. Aux Plains river. (F., 85.)

12. Indiana.

1. Elkhart river, Rome City, Noble county. (F., '85.)
2. [Trib. Wabash R.], Delphi, Carroll county. (Hay, '96.)
3. [White R.], Indianapolis, Irvington, and Millersville, Marion county. (Hay, '96.)
4. [Lake Michigan], Michigan City, Laporte county. (Hay, '96.)
5. Lake Maxinkukee and Twin Lakes, Marshall county. (Hay, '96.)
6. Turkey lake, Kosciusko county. (Hay, '96.)
7. Indian lake, Waterloo, De Kalb county. (Hay, '96, and F., '98.)
8. Turman creek, Sullivan county. (Hay, '96.)
9. [Wabash R.], Lafayette, Tippecanoe county. (Hay, '96.)
10. Clear creek, Bloomington, Monroe county. (F., '85, and Hay, '96.)
11. [Trib. White R.], Switz City, Greene county. (Hay, '96.)
12. [White Water R.], Brookville, Franklin county. (Hay, '96.)
13. Salt creek, Brown county. (Hay, '96.)
14. White river. (F. '85.)

14. Iowa.

1. Des Moines river, Ottumwa, Wapello county. (F., '85.)
2. [Mississippi R.], Davenport, Scott county. (F., '85.)

21. Michigan.

1. St. Clair river [St. Clair county]. (F., '85.)
2. Detroit river [Wayne county]. (F., '85.)
3. [Trib. Detroit R.], Northville [Wayne county]. (F., '85.)
4. Huron river, Ann Arbor [Washtenaw county]. (F., '85.)
5. Saginaw river. (F., '98.)
6. Lake Douglas [Cheboygan county]. (F., '98.)
7. [Lake St. Clair], Ecorse [Wayne county]. (F., '85.)
8. Kalamazoo river, Otsego [Allegan county]. (F., '85 and '90.)
9. [Kalamazoo R.], Marshall [Calhoun county]. (F., '90.)
10. St. Mary's lake, mouth of Battle creek [Calhoun county]. (F. '90.)

31. New York.

1. [Niagara R.], Niagara [Niagara county]. (F., '85.)
2. Grass river, St. Lawrence county. (F., '85.)
3. [Grass R.], Canton, St. Lawrence county. (F., '85.)
4. Black lake, St. Lawrence county. (F., '85.)
5. [St. Lawrence R.], Ogdensburg [St. Lawrence county]. (F., '85.)
6. Lake Ontario. (F., '85.)
7. Garrison creek, Sackett's Harbor [Jefferson county]. (F., '85.)
8. Four Mile creek, Oswego [Oswego county]. (F., '85.)
9. Oneida lake. (F., '85.)
10. Cayuga lake. (F., '85.)
11. [Lake Ontario]. Rochester [Monroe county]. (F., '85.)
12. [Lake Erie], Forestville, Chautauqua county. (F., '85.)

34. Ohio.

1. Portage river, at Oak Harbor, Ottawa county. (F., '98.)

37. Pennsylvania.

1. Alleghany and Monongahela rivers, and in many of the small streams throughout the county. Allegheny county. (Williamson, '01.)

48. Wisconsin.

1. Tributaries of Pecantonica river, Green county. (F., '85.)
2. [Trib. Rock R.], Madison [Dane county]. (F., '85.)

Cambarus propinquus sanbornii Fax.

16. Kentucky.

1. Smoky creek, Carter county. (F., '85.)

34. Ohio.

1. [Trib. Black R.], Oberlin [Lorain county]. (F., '85.)

Hay ('96) says: "This is probably the most abundant species in our state. It is usually found in large numbers in the smaller streams hiding under stones, concealed in short burrows along the banks, or resting quietly on the bottom." Ac-

cording to the same writer, Mr. Lewis McCormick reports *C. propinquus sanbornii* as the most abundant species at Oberlin, Ohio.

See, also, Faxon and Wyman, under *C. pellucidus*, and Hay, under *C. rusticus*.

Cambarus pubescens Fax.

9. Georgia.

1. McBean creek, tributary of the Savannah river, near Augusta, Richmond county. (F., '85.)
2. [Trib. Savannah R.], Richmond county. (F., '85.)
3. Buckhead creek, Millen, Burke county. (F., '98.)

Reported only from the territory of the two almost parallel rivers, Savannah and Ogeechee, in eastern Georgia.

Cambarus putnami Fax.

12. Indiana.

?1. [Trib. Ohio R.], Bradford, Harrison county. (Hay, '96.)
2. [White Water R.], Brookville, Franklin county. (Hay, '96.)
?3. [White R.], between Paoli, Orange county, and Wyandotte cave. (Hay, '96.)

16. Kentucky.

1. [Clinch R.], Cumberland Gap [Bell county]. (F., '85.)
2. Green river, near Mammoth cave [Edmonson county]. (F., '85.)
3. [Green R.], Grayson Springs, Grayson county. (F., '85.)

41. Tennessee.

?1. [Tennessee R.], Knoxville, Knox county. (F., '85.)

Cambarus rusticus Gir.

Lake Superior. (F., '85.)

1. Alabama.

1. Cypress creek, Lauderdale county. (F., '85.)

2. Arkansas.

1. White river, Eureka Springs, Carroll county. (F., '85.)
2. Black river, Black Rock [Lawrence county]. (F., '98.)

11. Illinois.

1. [Trib. Illinois R.], Normal [McLean county]. (F., '85.)
2. [Mississippi R.], Quincy [Adams county]. (F., '85.)

12. Indiana.

1. [White R.], Indianapolis [Marion county]. (F., '85.)
2. White river. (F., '85.)
3. Ohio river, Madison [Jefferson county]. (F., '85.)
4. White river and Irvington, Marion county. (Hay, '96.)
5. [Wabash R.], Waterloo, De Kalb county. (Hay, '96.)
6. [White Water R.), Brookville, Franklin county. (Hay, '96.)

14. Iowa.

1. Lizard creek, Fort Dodge [Webster county]. (F., '85.)
2. Shell Rock river, Waverly [Bremer county]. (F., '98.)
3. Indian creek, Marion [Linn county]. (F., '98.)

15. Kansas.

1. Osage river, La Cygne [Linn county]. (F., '90.)

16. Kentucky.

1. Kentucky river, Little Hickman [Jessamine county]. (F., '85.)
2. [Kentucky R.], Perryville, Boyle county. (F., '85.)
3. Salt river [Bullitt county]. (F., '85.)
4. [Mississippi R.], Moscow, Hickman county. (F., '98.)

21. Michigan.

1. [Shiawassee R.], Saginaw [Saginaw county]. (F., '98.)
2. [——— R.], Tiffin [——— county]. (F., '98.)

24. Missouri.

1. Osage river. (F., '85.)
2. [James R.], Springfield [Greene county]. (F., '98.)
3. [Osage or White R.], Marshfield [Webster county]. (F., '98.)
4. Meramec river, Dent county. (F., '90.)
5. Stream flowing from Galloway cave, Galloway, Greene county. (Harris, '02.)

34. Ohio.

1. Kelley's island, Lake Erie. (F., '85.)
2. Miami river, Dayton [Montgomery county]. (F., '85.)
3. Yellow Springs [Greene county]. (F., '85.)
4. Ohio river, Cincinnati [Hamilton county]. (F., '85.)
5. [Maumee R.], Grand Rapids, Wood county. (F., '98.)
6. [Maumee R.], Defiance, Defiance county. (F., '98.)
7. [Maumee R.], Ottawa, Putnam county. (F., '98.)
8. [Sandusky R.], McCutchenville, Wyandot county. (F., '98.)
9. [Sandusky R.], Tiffin, Seneca county. (F., '98.)

37. Pennsylvania.

1. [Ohio R.], Pittsburg [Allegheny county]. (F., '85.)
2. [Delaware R.], Philadelphia county. (F. '85.)
3. Ohio river, Neville island, Allegheny county. (Williamson, '01.)

41. Tennessee.

1. [Cumberland R.], Lebanon [Wilson county]. (F., '85.)
2. [Clinch R.], Cumberland Gap [Claiborne county]. F., '85.)
3. Harpeth river, Franklin [Williamson county]. F., '90.)

42. Texas.

1. In Texas. (F., '85.)

48. Wisconsin.

1. [Lake Michigan], Racine [Racine county]. (F., '85.)
2. [Trib. Mississippi R.], Beloit [Rock county]. (F., '85.)
3. [Trib. Wisconsin R.], Ironton [Sauk county]. (F., '85.)
4. Fox river (W. F. Bundy [*C. placidus*]). (F., '85.)

Hay ('96) says: "This species has very much the same habits as *C. propinquus*, and the two are often found in company."

Cambarus setosus Fax.

24. Missouri.

1. Wilson's cave and in wells, Jasper county. (Garman, '89, and Faxon, '90.)
?2. In stream from cave on branch of Finley creek, cave region of Christian county, near Ozark. (Broadhead, '74). Referred to this species on account of locality by Faxon ('90).

So far as yet known, this species is confined to the southwestern portion of Missouri. Jasper county (24, 1) is drained west into the Neosho or Grand river, which flows south through Indian Territory into the Arkansas, while Finley creek empties into James fork of White river, which enters the Mississippi at about the same point as the Arkansas. While in Greene county, Missouri, in the spring of 1901, I was told that there occur white crayfish in Galloway cave (for description see *C. neglectus*), but was unable to secure any specimens. The stream flowing from Galloway cave, at Galloway, about eight miles southeast of Springfield, empties into the James river, so that the two localities, about twenty miles apart, are directly connected by water. It may be that very light specimens of *C. neglectus* have been sometimes mistaken for "white crayfish."

C. setosus was described by Faxon in Garman's paper ('89), and again in his own paper ('90), from material collected in wells and caves in southwestern Missouri by Miss Ruth Hoppin.

Garman ('89) says: "The cave belt of Missouri is 150 or more miles in width, and extends diagonally quite across the state from northeast to southwest. . . . The geological position of the caves ranges from the St. Louis limestone of the Lower Carboniferous to the third magnesian limestone of the Lower Silurian. . . . The caves appear to become more extensive and more numerous toward the southwestern portion of the state. . . . The statement is made that Conner's cave, in Boone county, has been explored for a distance of eight miles. . . . The sink-holes with which so many of the caverns are connected prove the manner of forming to have been the same as that giving rise to the Mammoth and other caves of Kentucky. . . . There seems to be no reason to suppose

the history of the majority of these caves goes further back than that of the later Tertiary deposits, if so far. Such a small amount of divergence as exists between the species peculiar to the caves and their allies outside is proof that the former have entered their subterranean dwellings at a comparatively recent period."

The following notes, giving a quite fair idea of the surroundings, are quoted from Miss Hoppin's letters, published by Garman ('89) and by Faxon ('90) :

"Wilson's cave is about fifty feet long, nearly as wide, oven-shaped, and high enough to stand erect except around the sides, The farmer had enlarged the entry to use the place as a creamery. A small, very clear stream flowed along the left side, having a width of two feet and a depth of three, with a temperature of 54+ deg. F. About ten feet from the entrance, the light struck the stream in such a manner that we could see everything in the water without a lantern. The first things that caught the eye were a lot of white crayfish, a dozen in all, like those I took from the wells. It seemed as if I might take every one of them. But, though blind, they have one or more of the other senses very keenly developed. I am very sure they, as well as the white fishes [*Typhlichthys subterraneus* Gir.], have their tactile sense developed in an unusual degree. At the least touch upon the water they dart away. As the net cautiously follows, they escape adroitly, making no blunders as to the direction of the approaching enemy, and hide in crevices of the jutting rocks or in the muddy bottom of the stream. The mud was easily stirred so that nothing could be seen. These creatures, fish and crayfish, are only to be secured by patient waiting and skilful management. The people at the cave say the fish never bite, and cannot be taken with hook and line. The crayfish were all found near the entrance, where there is considerable light. Following the stream back to a dark recess, reached by crawling on the slippery rocks, the light of the lantern revealed a school of little, white fishes such as I secured from the wells. All were very small. I saw half a dozen or more, but secured only one. I concluded that the crayfish liked the light. Perhaps they remain near the entrance because they find there a supply of food. We found a few snails floating about, but saw none in the dark pool where the fish were.

Miss Wilson, who was with me, thinks the crayfish devour the others. She has never seen them together, and says the latter keep away from the former, though she had not noticed the crayfish catching or eating them. There was nothing to prevent the crayfish ascending the stream to where the others were."

. . . . . .

"On my first visit, the water being low, no crayfish were seen in the dark nook, the place favored by the fish. After the storm, which had flooded the caves, a few were found there. Though I watched for some time I never saw them pursue the fishes, as they might easily have done, guided by the stir in the water. Both creatures are very sensitive to the slightest ripple. During high water, a pool, 'the lake,' is formed a little way from the stream in another dark part of this cave. In low water this pool is cut off from the creek. I found both species in it, the fish in the darkest part, and saw no signs of enmity. Most of the crayfish were found in the lower part of the stream in the twilight; the fishes could not be found without the lantern. At the time of the floods the cave is full and the water rushes out furiously. Another proof that the crayfish are more fond of the light is seen in the shallower wells. That from which most were taken was more exposed to the sun. At noon, when the light was more favorable, we could see them swimming about. No fishes have been taken from this well. They are taken in the narrower, more shaded wells, of which the deep ones on the hills report fishes only.

"As to the food of the fishes, I discovered nothing. The mud where they were was not so deep as farther down. An examination of the length of the cave brought to light many snails; the shells of the living ones are whiter and more nearly transparent than the floating dead ones. The largest crayfish are of a dirty, rusty color, and very bristly, in caves and wells. One large one is very soft and very white. No doubt it is newly molted."

"Both fish and crayfish were less numerous after the freshet, and apparently less active. The disturbance of the flood may have caused them to retreat into their hiding-places, only the weaker being left behind, or some may have been swept away by the torrent. The sensitive creatures would soon die in the

light and heat outside, where the water is full of frogs and eyed crayfishes. . . . The specimens become opaque when put into alcohol; they are almost transparent when alive, so much so that the action of their internal organs can be observed. Repeated tests assured me the animals were blind, though very sensitive to the sunlight. They died soon after catching, even in water frequently changed."

"The wells from which specimens have been taken are about half a mile from Center creek, the water-level in wells and creeks being nearly the same. The wells were nine or ten in number, from five to eighty rods apart, from eleven to thirty feet in depth, deeper in the higher ground, and having a depth of water varying from two to four feet. In some wells the rock at the bottom had been excavated. The water is what is commonly called hard—*i. e.*, impregnated with lime. After rains some of the wells have softer water than others, and the water stands higher in these wells, indicating closer connection with surface-drainage. All of the wells soon regain the common level. They become low in times of drought, but never dry out entirely, as is the case with a cave spring near by, about twelve feet above the level of the creek. The temperatures taken in the wells at low water ranged from 52+ deg. to 54+ deg. F. During a storm, in the well having the highest water, the temperature rose to 57+ deg. When the mercury stood at 90 to 95 deg. outside the temperature was only 54 deg. in Wilson's cave."

Cambarus schufeldtii Fax.

17. Louisiana.

1. [Mississippi R. or Gulf of Mexico], near New Orleans [Orleans county]. (F., '85.)

Cambarus simulans Fax.[23]

15. Kansas.

1. [Trib. Smoky Hill R.], Fort Hays [Ellis county]. (F., '85.)
2. Tributary of Medicine Lodge river, Barber county. (F., '90.)
3. A slough near Halstead, Harvey county. (Harris, '00.)
4. A small branch of the Chikaskia river, six miles northeast of Caldwell, Sumner county. (Harris, '00.)
5. A stream near Wichita, Sedgwick county. (Harris, '02.)
6. A slough northeast of Caldwell, Sumner county. (Harris, '02.)

23. Professor Hay informs me that he has examined the types of *C. gallinus* Ckl. and Porter, in the United States National Museum, and concludes that the material should be referred to *C. simulans*. In this paper, the material described by Cockerell and Porter, and the material which I provisionally referred to *C. gallinus* in former papers, will be treated under *C. simulans*.

30. New Mexico.

1. Abundant in the Gallinas river at Las Vegas and in the neighboring waters [San Miguel county]. (Cockerell and Porter, '00.)
2. In lakes near Watrous [San Miguel county]. (Cockerell and Porter, '00.)
3. In irrigating canal at Roswell, Chaves county. (Cockerell and Porter, '00.)

42. Texas.

1. [Trinity R.], Dallas [Dallas county]. (F. '85.)
2. [Canadian or Red R.], east of Canadian river. (F., '85.)

Faxon ('84 and '85) reports this species in pools west of the hundredth meridian, east of the Canadian river, probably within the limits of Texas.

According to Cockerell ('00), and Cockerell and Porter ('00), *C. gallinus* is abundant in the Gallinas river, at Las Vegas, and in neighboring waters; also found in lakes near Watrous, N. M., and at Roswell.

The material arranged preliminary to *C. gallinus* by Harris ('00 and '02) was taken in a narrow strip of territory running north for about eighty miles from the southern boundary of Kansas and drained by the Arkansas river. Two small specimens, each slightly over an inch in length, were taken in a little running stream (Harris, '00). Material was taken in a slough near Halstead, Harvey county (Harris, '00), which connected in wet weather with a creek not a mile away. In July of 1900, when a part of the material was taken, the water was running more than usual, on account of recent rains, and no burrows were observed. About November 10, when the locality was again visited, specimens were taken from burrows. One of these, about one foot deep, had its mouth below the surface of the water. The others were along the bank, close to the water's edge. "Chimneys" were not very conspicuous. The burrows themselves, so far as noticed, were unbranched, about three inches in diameter, and extending almost straight down for a distance not to exceed one and one-half feet. One animal was found in each burrow.

A small slough four miles west of Caldwell, Sumner county (Harris, '02), had been dry all of the summer of 1901, owing to the very severe drought, but a spring a little distance from the edge still contained a small pool of water, perhaps three feet in diameter, although the water had ceased to flow into the slough. In the small pool were noticed a number of small specimens, about one inch in length, and, while none were taken, they undoubtedly belonged to the same species as the

adults taken in the same place. In digging a well in the old spring, eight adult specimens were secured, two males and six females. They had burrowed down through the loose surface soil for from six to thirty-six inches, depending upon whether the burrows were in the center or upon the edge of the old basin of the spring. The burrows, about two inches in diameter and provided with chimneys above, went down almost perpendicularly until they came to the surface of a stratum of Wellington shale. Here they were enlarged into almost round chambers, about ten inches in diameter, and not more than three inches in height. The crayfish had burrowed down a little ways into the rather disintegrated shale. The excavations of the shale were conical, about four inches in diameter at the top and four inches deep. In these chambers the crayfish, not very active or pugnacious when found, were taken. Mr. Kinnear, who collected the material, thought that as the shale was softened by the water the crayfish had removed it bit by bit. There were about three or four of the main burrows coming from the upper surface, terminating in the large chambers as described above. These chambers were then connected by passageways running from one to another. Two of the specimens were taken August 1 and the other six August 25–27.

All the females were, with one exception, loaded with eggs, which appear, on examination with a hand lens, to be in a very early stage of development, and have probably been only comparatively recently laid.

Prof. T. D. A. Cockerell, the author of *C. gallinus*, writes me as follows, November 5, 1902: "I have found remains of *C. gallinus* in the upper layer of our Pleistocene alluvium at Las Vegas, but as the creature burrows so much, I do not feel any assurance that the remains are really of the age of the deposit. They may very well be only a few hundred years old. The locality where they were found is not far from Green's lake, where the species still lives, and one has only to suppose that the lakes were formerly of larger size. At the same time, the creature may really have existed in the region when the deposits were formed."

In the same letter, Mrs. Cockerell, who is more familiar with the living animal, says: "These crayfish burrow in the muddy banks of the lakes and rivers where they live. We have col-

lected them from Green's lake, a semiartificial lake with mud bank, and the Gallinas river in the quiet pools. This river is a swiftly flowing mountain stream, with a rocky bottom in most places. Great numbers were found in the neighborhood of the irrigation dam. . . . Females taken in May had the swimmerets loaded with eggs."

In a letter of November 10, 1902, Mr. J. D. Tinsley, who collected *C. gallinus* at Roswell, N. M., informs me that he took his material in an irrigating canal when the water was quite low for a few hours. They were quite abundant and had burrowed considerable in the sides and possibly the bottom (?) of the canal below the usual water-level. He did not remember seeing any mud chimneys. The canal carries clear, very seldom muddy, water with a slow but decided current.

This species, then, is sometimes found in running streams and sometimes in burrows, apparently resorting to the burrow during dry weather.

Faxon ('85) says in his description: "The full cephalothorax and large abdomen seem to indicate that this is not preeminently a burrowing species, like its allies, *C. gracilis*, *C. advena*, etc."

Cambarus sloanii Bundy.

12. Indiana.

1. [Ohio R.], New Albany, Floyd county. (Hay, '96.)
2. [Ohio R.], Madison, Jefferson county. (Hay, '96.)
3. [Blue R.], Marengo, Crawford county. (Hay, '96.)

16. Kentucky.

1. In Kentucky (*fide* Bundy). (F. '85.)

So far as yet reported, it is confined to southeastern Indiana.

Hay ('96) says: "This species is quite abundant in southern Indiana, frequenting the muddy banks of running streams. Doctor Sloan, for whom the species was named, has made observations on its habits as follows: 'He commences on the bank of the stream, burrows below the bed, and has an opening two or more feet out in the stream, where he sits watching for anything that may turn up, with a safe retreat.'"

Cambarus spiculifer LeC.

9. Georgia.

1. Oconee river, at Athens [Clarke county], and Milledgeville [Baldwin county]. (F., '85.)
2. Ocmulgee river, in the neighborhood of Atlanta [Fulton county]. (F., '85.)
3. Chattahoochee river, at Roswell, Cobb county, and near Gainesville [Hall county]. F., '85.)
4. Etowah river. (F., '85.)

Cambarus spinosus Bundy.

1. Alabama.

1. Cypress creek, Lauderdale county. (F., '85.)
2. [Big Nance creek], Courtland [Lawrence county]. (F., '98.)

9. Georgia.

1. [Etowah, Oostenaula or Coosa R.], neighborhood of Rome [Floyd county]. (F., '85.)

32. North Carolina.

1. Tar river, Rocky Mount [Nash county]. (F., '90.)

39. South Carolina.

1. Saluda river. (F., '85.)

41. Tennessee.

1. Indian creek, tributary of Powell's river, six miles southeast of Cumberland Gap [Claiborne county]. (F., '98.)
2. Clinch river, at Walker's Ford, eleven miles southwest of Tazewell [Claiborne county]. (F., '98.)
3. Tennessee river, near border of Georgia [Dode county (?)]. (F., '85)

Cambarus stygius Bundy.

48. Wisconsin.

1. Shores of Lake Michigan, having been washed up during a storm. (F., '85.)

Cambarus troglodytes LeC.

9. Georgia.

1. Lower Georgia. (F., '85.)
2. Savannah river, Richmond county. (F., '85.)

11. Illinois.

?1. [Trib. Illinois R.], Lawn Ridge, Marshall county. (F., '85.)

39. South Carolina.

1. [Atlantic O.], Charleston [Charleston county]. (F., '85.)
2. [Cooper R.], Oakley [Berkley county]. (F., '85.)
3. [Congaree R.], Columbia [Richland county]. (F., '85.)

LeConte ('56) says of *A. troglodytes:* "Habitat in Georgiæ Oryzaceis, ubi spiracula 4 unc. alta format"; and of *A. fossorum* [or *C. troglodytes*]: "Habitat in fossis Georgiæ inferiores."

Cambarus typhlobius JOSEPH.

Caves at Carniola. A species of especial interest, since it is the only one found outside of America.

Cambarus uhleri FAX.

19. Maryland.

1. [Assateague bay and Pocomoke R.], Worcester county. (F., '85.)
2. [Potomac R.], Somerset county. (F., '85.)
3. [Potomac R.], Wicomico county. (F., '85.)
4. [Chesapeake bay or Potomac R.], St. Mary's county. (F., '85.)
5. [Chesapeake bay], Talbot county. (F., '85.)
6. [Chesapeake bay], Dorchester county. (F., '85.)
7. [Choptank R.], Caroline county. (F., '85.)

Faxon ('85) says: "This species was discovered in the counties of Maryland enumerated above, on the Chesapeake and Atlantic coasts of Maryland. It is found in salt marshes, covered twice daily by the tides, and also in brackish and freshwater ditches in company with *C. blandingii*. In Dorchester county, it is found far back in the lowlands in the neighborhood of Vienna."

Cambarus versutus HAG.

1. Alabama.

1. [Mobile bay], neighborhood of Mobile [Mobile county]. (F., '85.)
2. [Escambia R.], Pollard [Escambia county]. (F., '98.)
3. [Trib. Coosa R.], Colora [Shelby county]. (F., '98.)
4. [Trib. Escambia R.], Greenville, Butler county. (F., '98.)
5. Escambia river at Flomaton [Escambia county], above Pensacola [Fla.] (F., '85.)

8. Florida.

1. [Pensacola bay ?], Cape Barrancas. (F., '85.)

Cambarus virilis HAG.

Canada.

1. Lake Winnepeg. (F., '85.)
2. Saskatchewan river. (F., '85.)
3. Red River of the North. (F., '85.)
4. [Lake Ontario], Toronto [York county]. (F., '85.)

?5. [St. Lawrence R.], Montreal. (F., '85.)

1. Alabama.

1. [Tennessee R.], near Bridgeport, Jackson county. (F., '85.)

2. Arkansas.

1. White river, Eureka Springs, Carroll county. (F., '85.)
2. [Trib. Illinois R.], Prairie Grove, Washington county. (F., '90.)
3. [Trib. Illinois R. or of White R.], Fayetteville, Washington county. (F., '90.)

11. Illinois.

1. [Illinois R.], Lawn Ridge, Marshall county. (F., '85.)
2. [Sangamon R.], Decatur, Macon county. (F., '85.)
3. [Trib. Illinois R.], Normal, McLean county. (F., '85.)
4. [Illinois R.], Pekin, Tazewell county. (F., '85.)
5. [Illinois R.], Geneva, Kane county. (F., '85.)
6. [Mississippi R.], Quincy, Adams county. (F., '85.)
7. [Mississippi R.], Cairo, Alexander county. (F., '85.)
8. Stillman's creek, Marion, Ogle county. (F., '85.)

12. Indiana.

1. Elkhart river, Goshen, Elkhart county. (Hay, '96.)
2. Twin Lakes, Lima, Lagrange county. (Hay, '96.)
3. Elkhart river, Rome City, Noble county. (F., '85, and Hay, '96.)
4. Lake Michigan, Michigan City, Laporte county. (Hay, '96.)
5. Long lake, Noble county. (Hay, '96.)
6. Turkey lake, Kosciusko county. (Hay, '96.)
7. [Kankakee R.], Shelby, Lake county. (Hay, '96.)

13. Indian Territory.

1. Five Mile creek, tributary of Spring river, one mile south of Kansas line, near Baxter Springs, Kan. (F., '90.)
2. [Trib. Gaines creek], McAlester [Choctaw Nation]. (F., '98.)

14. Iowa.

1. [Mississippi R.], Davenport [Scott county]. (F., '85.)
2. [Mississippi R.], Burlington [Des Moines county]. (F., '85.)
3. [Des Moines R.], Fort Dodge [Webster county]. (F., '85.)
4. Des Moines river. (F., '85.)
5. [Trib. Missouri R.], Bedford [Taylor county]. (F., '85.)
6. [Wapsipinicon R.], Springvale [Linn county]. (F., '85.)
7. Spirit lake, Dickinson county. (F., '98.)
8. [Des Moines R.], Ames, Story county. (F., '98.)
9. Storm lake, Buena Vista county. (F., '98.)
10. [Little Sioux R.], Cherokee, Cherokee county. (F., '98.)
11. Yellow creek, Pottsville, Allamakee county. (F., '98.)
12. Spring creek, Delhi, Delaware county. (F., '98.)
13. Boyer river, Arion, Crawford county. (F., '98.)
14. [Iowa R.], Belmond, Wright county. (F., '98.)
15. Shell Rock river, Waverly, Brenner county. (F. '98.)

15. Kansas.

1. Tributary of Kansas river, Shawnee county. (F., '85 *b*.)
2. Ward's creek, Shawnee county. (F., '85 *b*.)
3. [Kansas R.], Wabaunsee county. (F., 85 *b*.)
4. [Arkansas R.], Garden City, Finney county. (F., '85 *b*.
5. Leavenworth, Leavenworth county. (F., 85 *b*.)
6. [Kansas R.], Manhattan, Riley county. (F., '85 *b*.)
7. Republican river, northwest of Fort Riley. (F., '85 *b*.
8. [Smoky Hill R. or trib.], Ellis county. (F., '85 *b*.)
9. Sappa creek, Oberlin, Decatur county. (F., '90.)
10. Osage river, La Cygne, Linn county. (F., '90.)
11. [Kansas R.], Topeka, Shawnee county. (F., '90.)

12. Spring at head of Medicine Lodge river, Kiowa county. (Harris, '00.)
13. Stagnant ponds, Douglas county. (Harris, '00.)
14. Rock creek, Douglas county. (Harris, '00.)
15. Washington creek, Douglas county. (Harris, '00.)
16. Coon creek, Douglas county. (Harris, '00.)
17. Wild Horse creek, Jefferson county. (Harris, '00.)
18. [Trib. Kansas R.], in small stream, Dickinson county. (Harris, '00 and '02.)
19. A small branch of Chikaskia river, six miles northwest of Caldwell, Sumner county. (Harris, '00.)
20. Small stream near Egerton, Wyandotte county. (Harris, '00.)
21. Labette creek, within city limits of Parsons, Labette county. (Harris, '00.)
22. Wakarusa river, Douglas county. (Harris, '02.)
23. Bull Foot creek, Lincoln county. (Harris, '02.)
24. Spillman creek, Lincoln county. (Harris, '02.)
25. Wildcat creek, about two miles west of Manhattan, Riley county. (Harris, '02.)
26. Lower part of Kansas river, near Lawrence [Douglas county]. (Harris, '02.)
?27. Among some of my old notes I find that on March 29 or 30, 1895, I secured, in an irrigating ditch near Atwood, Rawlins county, four or five crayfishes, among which was one large female carrying a large numbor of eggs. On April 13, 1895, in the same ditch, was secured, hiding under a weed, another female with eggs. These specimens I place with this species, although it might just as well be *C. neglectus*; *C. neglectus* (3) and *C virilis* (9) having been taken at the same place, and *C. neglectus* (2) a few miles to the west. The eggs of *C. virilis* are carried in the spring (Harris, '00), as are also those of *C. neglectus* (Harris, '02). There is an error in the map given by Harris ('02), in that the 7 and the 10 should both be in Decatur county instead of the 7 in Decatur and the 10 in Rawlins county.

21. Michigan.

1. Spencer creek [——— county]. (F., '90.)
2. Barnum lake, south of Battle Creek [Calhoun county]. (F., '90.)
3. Lake Douglas [Cheboygan county]. (F., '98.)

22. Minnesota.

1. Lake Superior. (F., '85.)
2. Mississippi river. (F., '85.)
3. Lake Minnetonka [Hennepin county]. (F., '85.)
4. Minnehaha creek, Cedar Lake [——— county]. (F., '85.)
5. Bassett's creek and Lake Independence [Hennepin county]. (F., '85.)

24. Missouri.

1. [Mississippi R.], St. Louis [St. Louis county]. (F., '85.)
2. Osage river. (F., '85.)
3. Trib. Meramec R], Irondale, Washington county. (F., '85.)
4. Bear creek and Hickson creek, Columbia [Boone county]. (F., '90.)
5. West fork of Black river, Reynolds county. (F., '90.)
6. [Trib. Neosho R], Jasper county. (F., '98.)
7. [Trib. Neosho R.], Neosho, Newton county. (F., '98.)
8. [Missouri R.], Kansas City [Jackson county]. (Harris, '02.)
?9. Wells in Jasper county. (F., '90.)

26. Nebraska.

1. [Missouri R.], Omaha [Douglas county]. (F., '85.)
2. Blue river, Crete, Saline county. (F., '98.)

31. New York.

?1. Lake George. (F., '85.)

33. North Dakota.

1. Red River of the North, near Pembina [Pembina county]. (F., '85.)
2. Souris or Mouse river. (F., '85.)

41. Tennessee.

?1. [Tennessee R.], Lebanon [Marion county]. (F., '85.)

42. Texas.

1. Red river, Arthur [Lamar county]. (F., '98.)

48. Wisconsin.

1. [Fox R.], Appleton [Outagamie county]. (F., '85.)
2. Baraboo river, Ironton [Sauk county]. (F., '85.)
3. Wisconsin river, Sauk City [Sauk county]. (F., '85.)
4. Sugar river [Green county]. (F., '85.)
5. Rock river, Rock county. (F., '85.)
6. [Lake Koshkong], Jefferson [Jefferson county]. (F., '85.)
7. [Lake Michigan], Milwaukee [Milwaukee county]. (F., '85.)

49. Wyoming.

1. [Laramie R.], near Laramie City [Albany county]. (F., '85.)

Street's ('77) types of *C. cousei*, twenty-two in number, were taken from the stomach of a pelican shot in May, 1873, on the Red River, near Pembina (?). The bird was sick and not able to fly; so the crayfish were supposed to have been taken in that vicinity. He quotes Doctor Coues's notes on *C. virilis* collected in Souris or Mouse river, in Dakota: "In bed of stream among stones, in shallow water. Very abundant."

Bundy ('83) says: "One of our most abundant species, frequenting running streams."

Faxon ('90) reports two small specimens of *Cambarus*, with well-developed eyes, taken, together with *C. setosus*, by Miss Ruth Hoppin, in Jasper county, Missouri, as probably belonging to this species.

Hay ('96) reports *C. virilis* as being confined in Indiana to lakes and streams in the northern part of the state, where it is extremely abundant and attains a large size.

According to Harris ('00), *C. virilis* is found principally in running streams, although frequently taken in the same localities as *C. immunis*. While he never took *C. virilis* from burrows, he has no doubt that the great numbers of burrows which

are seen running back into the banks of the creeks just a little below the water line belong to this species. When living in the same sort of habitat as *C. immunis*, it doubtless burrows in the same manner. A specimen from Kansas City, Mo. (24, 8), was found by laborers nine feet under ground and considerably over 100 feet from water. *C. virilis* seems to prefer rocky rather than muddy places. May 5, 1900, he collected this species in Wild Horse creek, Jefferson county, Kansas. At the rocky riffles the crayfish were taken in abundance, but perhaps 150 yards above, where the bottom was composed of soft, deep mud, he did not secure a single specimen. The same thing was noticed in Coon creek, Douglas county, Kansas, and Mr. C. D. Bunker told him that in Rock creek, Douglas county, Kansas, he noticed that the animals are to be found only in the rocky places. Perhaps it finds among the rocks more ready protection from its enemies. So far as could be seen, food would be just as plentiful, if not more so, in the slower running, muddy parts of the stream than at the rocky riffles. *C. virilis* can and does live in muddy places. It is sometimes found in muddy ponds and roadside ditches with *C. immunis*, and he took a great many from Washington creek, Douglas county, Kansas, when the mud was as soft and deep as in either of the creeks mentioned above. In the winter *C. virilis* may be found under flat stones in the rocky creeks, even when the water is covered with ice. When taken from the water, they are so numb as to be almost incapable of movement, but liven up when held in the hand for a short time, and are as lively as ever after a few hours in the laboratory.

The eggs are laid in the spring, none being found on the females collected during the winter. The ovarian eggs of specimens taken in January seem to be fully developed, so far as may be seen from examination with the naked eye. Harris ('02) gives two lots of material as taken under stones in shallow running water.

Cambarus weigmanni Erichs.

Mexico.

1. Mexico. (F., '85.)
?2. [Gulf of Mexico], Jalapa [Jalapa]. (F., '85.)
?3. [Gulf of Mexico], Isthmus of Tehuantepec. (F., '85.)

DISTRIBUTION BY RIVER SYSTEMS.

In the following table the distribution of the different species by river systems is shown. The arrangement I have adopted is a simple one, the rivers emptying into the sea being arranged in order, from those of Hudson Bay to the Gulf of Mexico. Under each of these rivers, the tributaries are arranged in order from the mouth towards the source, and the tributaries of these are arranged in the same way. The names of streams flowing into the sea are printed in capitals; tributaries of the first, second and third order in small capitals, italics, and lower case, respectively. In some cases subdivisions have been made for large bays. In the case of the St. Lawrence river system, separate parts, as the Great Lakes and the Niagara river, have been most conveniently treated as separate tributaries of the St. Lawrence river as the term is generally understood.

Under the different streams are given alphabetical lists of the species reported from them, with references to the number of the state and the number of the locality in the state which is referred to this water system; *C. carolinus*, 41, 1, refers to "1. Clinch R., Cumberland Gap, Claiborne county. (F., '85)." In assigning certain localities to a drainage system, considerable difficulty has been experienced, especially in swampy regions, as northern Indiana and the most of Florida, but I feel confident that the most of the localities are correctly assigned. In many cases it has not been possible to determine from the localities given to what stream a species really belongs, and in the table it has been placed under both possible systems, the reference to the catalogue number followed by a question mark in parentheses, *C. bartonii*, 29, 2 (?), under both Raritan and Delaware rivers. The intention of this table is to place each locality in its proper drainage system. The species which are given under Atlantic ocean and Gulf of Mexico are from localities which could not well be assigned to any river, and probably all the localities are drained immediately into the ocean or swampy coast region.

The arrangement is in the main an artificial one, but it possesses certain advantages, and seems the best, all things consid-

ered. For certain localities it was impossible to determine the drainage system, and others, as those of *C. pellucidus*, it is not considered advisable to assign to streams. Of these species a list is given at the end of the table.

To facilitate use of the table, an index of species, the numbers referring to the numbers of the streams in the table, is given at the beginning:

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5. **ATLANTIC OCEAN.**
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6. ST. LAWRENCE RIVER.
C. bartonii. C., ?1; 31, 2, 5.
C. bartonii robustus. 31, 4, 5, 8.
C. propinquus. C., 1; 31, 2, 3, 4, 5.
C. virilis. C., ?5.

7. RICHELIEU RIVER.

8. *Lake Champlain.*
C. bartonii. 31, 1; 44, 1.

9. Lake George.
C. virilis. 31, ?1.

10. LAKE ONTARIO.
C. argillicola. C., 1.
C. bartonii robustus. C., 1, 2; 31, 3.
C. propinquus. C., 2; 31, 6, 7, 8, 11.
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11. *Oneida Lake.*
C. bartonii. 31, 10.
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13. *Genesee River.*
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14. NIAGARA RIVER.
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C. argillicola. 34, 1, 2.
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16. *Sandusky River.*
C. rusticus. 34, 8, 9.

17. *Maumee River.*
C. rusticus. 34, 5, 6, 7.

18. *Huron River.*
C. propinquus. 21, 4.

19. DETROIT RIVER.
C. immunis. 21, 1.
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6. ST. LAWRENCE RIVER—*continued:*

20. Lake St. Clair.
    C. argillicola. 21, 1.
    C. diogenes. 21, 1.
    C. propinquus. 21, 7.

21. St. Clair River.
    C. propinquus. 21, 1.

22. Lake Huron.
    C. propinquus. 21, 6(?).
    C. virilis. 21, 3(?).

23. *Saginaw River.*
    C. argillicola. 21, 2.
    C. propinquus. 21, 5.
    C. rusticus. 21, 1.

24. Lake Michigan.
    C. blandingii acutus. 11, 8; 48, 1.
    C. diogenes. 11, 2, 6; 48, 3.
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    C. immunis. 48, 1.
    C. propinquus. 12, 1, 4; 21, 6(?).
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25. *Kalamazoo River.*
    C. propinquus. 21, 8, 9, 10.
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26. Lake Superior.
    C. affinis.
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27. RESTIGOUCHE RIVER.
    C. bartonii. C., 5.

28. UPSALQUITCH RIVER.
    C. bartonii. C., 6.

29. MIRAMICHI RIVER.
    C. bartonii. C., 7.

30. ST. JOHN RIVER.
    C. bartonii. C., 2, 3, 4; 18, 3, ?6.

31. PENOBSCOT RIVER.
    C. bartonii. 18, ?5.

32. KENNEBEC RIVER.
    C. bartonii. 18, 1, 3, ?4.

33. PROVIDENCE RIVER.
    C. bartonii. 20, 1.

34. PAWCATUCK RIVER.
    C. bartonii. 38, ?1.

35. HOUSATONIC RIVER.
C. bartonii. 20, ?4.

36. HUDSON RIVER.
C. bartonii. 20, 2, 3; 31, 3, 4, 7.
C. bartonii robustus. 31, 6.

37. PASSAIC RIVER.
C. bartonii. 29, 3.
C. blandingii. 29, 1.

38. RARITAN RIVER.
C. affinis. 29, 1 (?).
C. bartonii. 29, 2 (?).

39. NAVESINK RIVER.
C. affinis. 29, 5.

40. DELAWARE RIVER.
C. affinis. 29, 1 (?), 2, 3, 4; 37, 2, 3, 7, 8.
C. bartonii. 29, 1, 2 (?); 31, 6, 8; 37, 8, 13, 14.
C. blandingii. 29, 2.
C. diogenes. 29, 1 (?).
C. rusticus. 37, 2.

41. SCHUYLKILL RIVER.
C. affinis. 37, 1 (?).
C. bartonii. 37, 7.

42. CHESAPEAKE BAY.
C. affinis. 19, 5, 7, 8.
C. bartonii. 19, 6 (?).
C. blandingii. 19, 5.
C. diogenes. 19, 2 (?), 4.
C. uhleri. 19, 4 (?), 5, 6.

43. POCOMOKE RIVER.
C. blandingii. 19, 6 (?).
C. diogenes. 19, 5 (?).
C. uhleri. 19, 1 (?).

44. WICOMICO RIVER.
C. blandingii, 19, 6 (?).

45. CHOPTANK RIVER.
C. blandingii. 19, 1, 2, 3.
C. diogenes. 19, 3.
C. uhleri. 19, 7.

46. SUSQUEHANNA RIVER.
C. affinis. 37, 4, 5, 6.
C. bartonii. 19, 6 (?); 31, 9, 12; 37, 2, 3, 4, 5, 6, 9.

47. PATAPSCO RIVER.
C. affinis. 19, 6.
C. blandingii. 19, 1.
C. diogenes. 19, 1.

48. PATUXENT RIVER.
C. bartonii. 19, 7.
C. blandingii. 19, 4 (?).

42. CHESAPEAKE BAY—*continued:*
49. Potomac River.
C. affinis. 7, 1; 19, 1, 2, 3, 4; 45, 1.
C. bartonii. 7, 1, 2; 19, 1, 3, 4, 5, 8; 45, 10; 47, 4, 6, 7.
C. bartonii robustus. 19, 1.
C. blandingii. 19, 4 (?).
C. diogenes. 7, 1; 19, 2 (?); 45, 1, 6.
C. uhleri. 19, 2, 3, 4 (?).
50. *Shenandoah River.*
C. affinis. 45, 2.
C. bartonii. 45, 2, 12.
C. longulus. 45, 1.
51. Rappahannock River.
C. bartonii. 45, 9.
C. bartonii robustus. 45, 1.
C. diogenes. 45, 4.
52. James River.
C. bartonii. 45, 5, 7, 8.
C. blandingii. 45, 1, 3.
C. diogenes. 45, 5.
C. longulus. 45, 2, 3, ?6.

53. CHOWAN RIVER.
C. affinis. 45, 2.
C. bartonii. 45, 6, 11.
C. blandingii. 45, 2.

54. PAMLICO RIVER.
C. blandingii. 32, 1.
55. Tar River.
C. blandingii. 32, 7.
C. carolinus. 32, 1.
C. spinosus. 32, 1.

56. NEUSE RIVER.
C. acuminatus. 32, 3.
C. argillicola. 32, ?1.
C. bartonii. 32, 5.
C. blandingii. 32, 2, 3, 8.
C. diogenes. 32, 2.

57. CAPE FEAR RIVER.
C. acuminatus. 32, 4.
C. blandingii. 32, 6.
C. diogenes. 32, 1.

58. SANTEE RIVER.
59. Congaree River.
C. blandingii. 39, 3.
C. latimanus. 39, 2.
C. troglodytes. 39, 3.
60. *Saluda River.*
C. acuminatus. 39, 1.
C. blandingii. 39, 2.
C. latimanus. 39, 1.
C. spinosus. 39, 1.

58. SANTEE RIVER—*continued:*
61. WATEREE RIVER.
C. blandingii. 39, 1.
62. *Catawba River.*
C. acuminatus. 32, 1, 6.
C. bartonii. 32, 3 (?), 4.

63. COOPER RIVER.
C. troglodytes. 39, 2.

64. SAVANNAH RIVER.
C. blandingii. 9, 1, 2.
C. pubescens. 9, 1, 2.
C. troglodytes. 9, 2.

65. OGEECHEE RIVER.
C. pubescens. 9, 3.

66. ALLAMAHA RIVER.
67. OCONEE RIVER.
C. latimanus. 9, 1, 2.
C. lecontei. 9, 1.
C. spiculifer. 9, 1.
68. *Ocmulgee River.*
C. spiculifer. 9, 2.

69. ST. JOHNS RIVER.
C. alleni. 8, 1, 5.
C. clarkii. 8, 1.
C. fallax. 8, 1, 2 (?), 3, 4, 5, 6, 9 (?), 10 (?).

70. INDIAN RIVER.
C. fallax. 8, 7, 8, 9 (?).

71. **GULF OF MEXICO.**
C. alleni. 8, 2, 4.
C. argillicola. 23, 1.
C. blandingii acutus. 42, 2.
C. clarkii. 23, 1.
C. clypeatus. 23, 1.
C. latimanus. 23, 1.
C. schufeldtii. 17, 1 (?).
C. weigmanni. M., ?2, ?3.

72. CALOOSAHATCHEE RIVER.
C. alleni. 8, 3.

73. PEACE RIVER.
C. alleni. 8, 6.

74. SUWANEE RIVER.
C. fallax. 8, 10 (?).

75. APPALACHICOLA RIVER.

76. CHATTAHOOCHEE RIVER.
C. latimanus. 9, 3.
C. spiculifer. 9, 3.

77. PENSACOLA BAY.
C. clarkii. 8, 2.
C. versutus. 8, 1.
78. ESCAMBIA RIVER.
C. barbatus. 1, 1.
C. bartonii longirostris. 1, 1.
C. evermanni. 1, 1.
C. versutus. 1, 2, 4, 5.
79. MOBILE BAY.
C. blandingii acutus. 1, 1.
C. clarkii. 1, 1.
C. lecontei. 1, 1.
C. versutus. 1, 1.
80. MOBILE RIVER.
81. *Tombigbee River.*
C. blandingii acutus. 23, 1.
C. hayi. 23, 1, 2.
C. mississippiensis. 23, 2.
82. Black Warrior River.
C. blandingii acutus. 1, 2, 3.
C. latimanus. 1, 1, 3 (?).
83. *Alabama River.*
84. Cahaba River.
C. erichsonianus. 1, 1.
C. extraneus. 1, 1.
85. Coosa River.
C. spinosus. 3, 1 (?).
C. versutus. 1, 3.
86. Etowah River.
C. extraneus. 9, 1.
C. jordani. 9, 1.
C. spiculifer. 9, 4.
C. spinosus. 9, 1 (?).
87. Oostanaula River.
C. spinosus. 9, 1 (?).
88. PEARL RIVER.
C. diogenes. 23, 1.
C. lancifer. 23, 2.
88*b*. LAKE PONTCHARTRAIN.
C. clarkii. 17, 1.
C. blandingii acutus. 17, 2, 3.
89. MISSISSIPPI RIVER.
C. argillicola. 17, ? 1.
C. blandingii acutus. 11, 5; 14, 2; 17, 1; 23, 2; 24, 1; 41, 1.
C. clarkii. 17, 2.
C. diogenes. 11, 3; 14, 1; 24, 1.
C. diogenes ludoviciana. 17, 1.
C. gracilis. 14, 1; 24, 1.
C. immunis. 11, 1, 2; 22, 1; 24, 1.
C. immunis spinirostris. 41, 1.
C. palmeri. 41, 1.

89. MISSISSIPPI RIVER—*continued:*
C. propinquus. 14, 2.
C. rusticus. 11, 2; 16, 4; 48, 2.
C. schufeldtii. 17, 1 (?).
C. virilis. 11, 6, 7; 14, 1, 2, 11; 22, 2, 3, 4; 24, 1.

90. RED RIVER.
C. blandingii acutus. 13, 1; 42, 1.
C. neglectus. 42, 1.
C. palmeri longimanus. 13, 1; 42, 1.
C. simulans. 42, 2 (?).
C. virilis. 42, 1.

91. WASHITA RIVER.
C. blandingii acutus. 2, 3.

92. ARKANSAS RIVER.
C. carolinus. 13, 1.
C. meeki. 2, 1.
C. simulans. 15, 3, 5.
C. virilis. 15, 4.

93. *Canadian River.*
C. blandingii acutus. 13, 2, 3.
C. difficilis. 13, 1.
C. palmeri longimanus. 13, 2.
C. simulans. 42, 2 (?).
C. virilis. 13, 2.

94. *Illinois River.*
C. difficilis. 2, 1.
C. diogenes. 2, 1 (?).
C. meeki. 2, 2 (?).
C. neglectus. 2, 2 (?), 3.
C. virilis. 2, 2, 3 (?).

95. *Neosho or Grand River.*
C. gracilis. 15, 1 (?); 24, ?2.
C. nais. 15, 1 (?), 2 (?).
C. neglectus. 24, 5, 6.
C. setosus. 24, 1.
C. virilis. 13, 1; 15, 21; 24, 6, 7, ?9.

96. *Verdigris River.*
C. gracilis. 15, 1 (?).
C. nais. 15, 1 (?), 2 (?).

97. *Salt Fork Arkansas River.*
C. simulans. 15, 2, 4, 6.
C. virilis. 15, 12, 19.

98. WHITE RIVER.
C. blandingii acutus. 2, 1.
C. diogenes. 2, 1 (?).
C. longidigitus. 2, 1.
C. meeki. 2, 2 (?).
C. neglectus. 2, 1, 2 (?), 4; 24, 2, 3, 4.
C. rusticus. 2, 1; 24, 2, 3 (?), 5.
C. setosus. 24, ?2.
C. virilis. 2, 1, 3 (?).

89. MISSISSIPPI RIVER—*continued:*
98. White River.
99. *Black River.*
C. blandingii acutus. 2, 2.
C. hylas. 24, 1.
C. palmeri. 2, 2.
C. rusticus. 2, 2.
C. virilis. 24, 5.
100. St. Francis River.
C. diogenes. 2, 2.
C. lancifer. 2, 1.
C. palmeri. 2, 1, 3.
101. Ohio River.
C. argillicola. 12, 4.
C. bartonii. 12, 3; 16, 2; 34, 1, 2, 3, 5; 37, 1, 12 (?); 47, 3.
C. carolinus. 37, 1 (?).
C. diogenes. 16, ?1; 37, 2 (?).
C. propinquus. 37, 1 (?).
C. propinquus sanbornii. 16, 1.
C. putnami. 12, ?1.
C. rusticus. 12, 3; 16, 3; 34, 4; 37, 1, 3.
C. sloanii. 12, 1, 2, 3.
102. *Tennessee River.*
C. alabamensis. 1, 1.
C. bartonii. 32, 1, 3 (?); 41, 1, 3, 5, 6.
C. blandingii acutus. 1, 4, 5.
C. carolinus. 45, 1.
C. compressus. 1, 1.
C. erichsonianus. 41, 2, 3.
C. extraneus. 41, 1.
C. extraneus girardianus. 1, 1; 41, 1.
C. forceps. 1, 1; 41, 1.
C. immunis. 1, 1.
C. latimanus. 1, 2, 3 (?).
C. longulus. 32, 1; 41, 2.
C. putnami. 41, ?1.
C. rusticus. 1, 1.
C. spinosus. 1, 1, 2; 41, 3.
C. virilis. 1, 1; 41, ?1.
103. Clinch River.
C. bartonii. 16, 1; 41, 4.
C. bartonii longirostis. 41, 1; 47, 1.
C. carolinus. 41, 1.
C. forceps. 41, 2, 3.
C. longulus. 41, 3, 5.
C. putnami. 16, 1.
C. rusticus. 41, 2.
C. spinosus. 41, 1, 2.
104. Holston River.
C. bartonii. 32, 6 (?); 41, 2; 45, 3, 4.
C. bartonii longirostris. 41, 2.
C. forceps. 45, 1.
C. longulus. 41, 1; 45, 5.

89. MISSISSIPPI RIVER—*continued:*
101. Ohio River.
102. *Tennessee River.*
105. French Broad River.
C. acuminatus. 32, 2 (?), 5.
C. bartonii. 32, 2.
C. erichsonianus. 41, 1.
C. longulus. 41, 4.
106. Cumberland River.
C. bartonii. 16, 7.
C. latimanus. 41, 1.
C. rusticus. 41, 1, 3.
107. Wabash River.
C. argillicola. 11, 1.
C. blandingii acutus. 11, 9; 12, 1, 2 (?), 3 (?), 6.
C. diogenes. 12, 1 (?), 3, 8.
C. gracilis. 11, 4.
C. immunis. 12, 4 (?), 5, 7, 8.
C. immunis spinirostris. 12, 1.
C. propinquus. 12, 2, 6 (?), 7, 8, 9.
C. rusticus. 12, 5.
C. virilis. 12, 5 (?), 6 (?).
108. Patoka River.
C. indianensis. 12, 1, 2.
109. White River.
C. argillicola. 12, 1, 2, 3.
C. bartonii. 12, 1, 2, 4, 5.
C. blandingii acutus. 12, 2 (?).
C. diogenes. 12, 2, 4, 5, 6.
C. immunis. 12, 1, 2, 3.
C. propinquus. 12, 3, 10, 11, 13, 14.
C. putnami. 12, ?3.
C. rusticus. 12, 1, 2, 4.
110. Green River.
C. bartonii. 16, 5, 6.
C. cornutus. 16, 1.
C. diogenes. 16, ?2.
C. putnami. 16, 2, 3.
111. Kentucky River.
C. bartonii. 16, 3.
C. rusticus. 16, 1, 2.
112. White Water River.
C. propinquus. 12, 12.
C. putnami. 12, 2.
C. rusticus. 12, 6.
113. Miami River.
C. diogenes. 34, 2.
C. gracilis. 34, 1.
C. rusticus. 34, 23.
114. Scioto River.
C. bartonii. 34, 4.
C. diogenes. 34, 1.

89. MISSISSIPPI RIVER—*continued:*
101. Ohio River.
102. *Tennessee River.*
115. Great Kanawha River.
C. bartonii. 32, 6(?); 45, 1; 47, 2.
C. bartonii robustus. 45, 2.
C. longulus. 45, 4; 47, ?1.
116. Alleghany River.
C. bartonii. 37, 10, 11, 12(?).
C. bartonii robustus. 37, 1.
C. carolinus. 37, 11(?).
C. diogenes. 37, 1, 2(?).
C. obscurus. 37, 1(?).
C. propinquus. 37, 1.
117. Monongahela River.
C. bartonii. 37, 12(?).
C. carolinus. 37, 1(?); 47, 1.
C. propinquus. 37, 1.
118. Youghioughany River.
C. bartonii. 19, 2.
C. diogenes. 19, 6.
C. obscurus. 37, 1(?).
119. Meramec River.
C. harrisonii. 24, 1.
C. medius. 24, 1.
C. rusticus. 24, 4.
C. virilis. 24, 3.
120. Missouri River.
C. diogenes. 15, 1; 24, 2.
C. immunis. 14, 4, 5; 15, 2; 26, 2.
C. virilis. 14, 5, 13; 15, 5, 20; 24, 4, 8; 26, 1, 2.
121. *Osage River.*
C. bartonii. 24, ?1.
C. neglectus. 24, 1.
C. rusticus. 15, 1; 24, 1, 3, ?5.
C. virilis. 15, 10; 24, 2.
122. *Kansas River.*
C. diogenes. 15, 2.
C. gracilis. 15, 2.
C. immunis. 15, 3, 4.
C. immunis spinirostris. 15, 1, 2.
C. neglectus. 15, 1, 4.
C. virilis. 15, 1, 2, 3, 6, 11, 13, 14, 15, 16, 17, 18, 22, 25, 26.
123. Republican River.
C. neglectus. 15, 2, 3, ?5.
C. virilis. 15, 7, 9, ?27.
124. Solomon River.
C. pilosus. 15, 1.
125. Smoky Hill River.
C. immunis. 15, 1.
C. simulans. 15, 1.
C. virilis. 15, 8.

89. MISSISSIPPI RIVER—*continued:*
120. Missouri River.
122. *Kansas River.*
126. Saline River.
C. pilosus. 15, ? 2.
C. virilis. 15, 23, 24.
127. *Platte River.*
C. immunis. 26, 1.
128. South Platte River.
C. diogenes. 5, 2; 49, 1.
129. North Platte River.
C. immunis. 49, 1.
C. virilis. 49, 1.
130. *Little Sioux River.*
C. virilis. 14, 7, 10.
131. Illinois River.
C. blandingii acutus. 11, 1, 2, 3, 4, 6, 7.
C. diogenes. 11, 1, 4, 5.
C. gracilis. 11, 1, 3, 5 (?); 48, 1 (?).
C. immunis. 11, 34.
C. propinquus. 11, 3, 4, 5, 6.
C. rusticus. 11, 1.
C. troglodytes. 11, ? 1.
C. virilis. 11, 1, 3, 4, 5.
132. *Sangamon River.*
C. bartonii robustus. 11, 1.
C. gracilis. 11, 2.
C. virilis. 11, 2.
133. *Fox River.*
C. diogenes. 48, 2.
C. rusticus. 48, 4.
C. virilis. 48, 1.
134. *Kankakee River.*
C. blandingii acutus. 12, 4 (?), 5.
C. diogenes. 12, 7.
C. immunis. 12, 6.
C. propinquus. 12, 5.
C. virilis. 12, 7.
135. Des Moines River.
C. immunis. 14, 2.
C. propinquus. 14, 1.
C. rusticus. 14, 1.
C. virilis. 14, 3, 4, 8, 9.
136. Iowa River.
C. blandingii acutus. 14, 1.
C. diogenes. 14, 2.
C. immunis. 14, 1, 6.
C. virilis. 14, 14.
137. *Cedar River.*
C. immunis. 14, 3.
C. rusticus. 14, 2, 3.
C. virilis. 14, 15.

89. MISSISSIPPI RIVER—*continued:*

138. Rock River.
C. diogenes. 48, 1.
C. propinquus. 11, 1, 2; 48, 1, 2.
C. virilis. 11, 8; 48, 4, 5, 6.

139. Wapsipinicon River.
C. virilis. 14, 6.

140. Moquakita River.
C. diogenes. 14, 3.
C. virilis. 14, 12.

141. Turkey River.
C. neglectus. 14, 1.

142. Red River of the North and Minnesota River.
C. diogenes. 22, 1.
C. virilis. C., 3; 33, 1.

143. *Souris or Mouse River.*
C. virilis. 33, 2.

144. Wisconsin River.
C. blandingii acutus. 48, 2.
C. rusticus. 48, 3.
C. virilis. 48, 2, 3.

145. TRINITY RIVER.
C. blandingii. 42, ? 1.
C. simulans. 42, 1.

146. CLEAR CREEK.
C. clarkii. 42, 1.

147. BRAZOS RIVER.
C. argillicola. 42, 2.

148. GUADALUPE RIVER.
C. argillicola. 42, 1.
C. clarkii. 42, 2.

149. RIO GRANDE RIVER.
C. clarkii. 42, 4.

150. Pecos River.
C. simulans. 30, 1, 2, 3.

LOCALITIES NOT TABULATED.

C. acherontis, 8, 1, 2.
C. advena, 9, 1.
C. angustatus, 9, 1.
C. barbatus, 9, 1; 23, ? 1.
C. bartonii, 9, ? 1; 16, 4; 47, 5.
C. bartonii robustus, 41, ? 1.
C. blandingii, 23, 1; 31, 1; 32, 5.
C. carinatus, M., 1, 2, 3.
C. chaplanus, M., 1.
C. clarkii, 34, ? 1; 42, 3.
C. cubensis, Cuba, 1, 2.

C. digueti, M., 1.
C. diogenes, 5, 1; 41 ? 1.
C. gracilis, 12, ? 1.
C. hamulatus, 41, 1.
C. immunis, M., 1; 11, 5.
C. lancifer, 23, 1.
C. maniculatus, 9, 1.
C. mexicanus, M., 1, 2, ? 3, ? 4.
C. mississippiensis, 23, 1.
C. montezumæ, M., 1, 2, 3, 4, 5.
C. montezumæ areolatus, M., 1.
C. montezumæ dugesii, M., 1.
C. montezumæ occidentalis, M., 1.
C. nebrascensis, 26, 1.
C. pellucidus.
C. pellucidus testii.
C. propinquus, 11, 7; 12, 1.
C. rusticus, 21, 2; 42, 1.
C. sloanii, 16, 1.
C. troglodytes, 9, 1.
C. typhlobius.
C. virilis, 12, 2; 21, 1; 22, 4.
C. wiegmanni, M., 1.

DISTRIBUTION BY STATES.

Space need not be devoted to a table of species with the states in which they occur, since that information may be obtained from the systematically arranged list of species of the genus given in the introduction, but for convenience in studying distribution, a list of states, with the species occurring therein, is given.

Canada.

C. argillicola.
C. bartonii.
C. bartonii robustus.
C. propinquus.
C. virilis.

United States.

ALABAMA.

C. barbatus.
C. bartonii longirostris.
C. blandingii acutus.
C. clarkii.
C. compressus.
C. erichsonianus.
C. evermanni.
C. extraneus.
C. extraneus girardianus.
C. forceps.
C. immunis.
C. latimanus.
C. lecontei.
C. rusticus.
C. spinosus.
C. versutus.
C. virilis.

ARKANSAS.

C. blandingii acutus.
C. difficilis.
C. diogenes.
C. lancifer.
C. longidigitus.
C. meeki.
C. neglectus.
C. palmeri.
C. rusticus.
C. virilis.

COLORADO.

C. diogenes.

DISTRICT OF COLUMBIA.

C. affinis.
C. bartonii.
C. diogenes.

FLORIDA.

C. acherontis.
C. alleni.
C. clarkii.
C. fallax.
C. versutus.

GEORGIA.

C. advena.
C. angustatus.
C. barbatus.
C. bartonii.
C. blandingii.
C. extraneus.
C. jordani.
C. latimanus.
C. lecontei.
C. maniculatus.
C. pubescens.
C. spiculifer.
C. spinosus.
C. troglodytes.

ILLINOIS.

C. argillicola.
C. bartonii robustus.
C. blandingii acutus.
C. diogenes.
C. gracilis.
C. immunis.
C. propinquus.
C. rusticus.
C. troglodytes.
C. virilis.

INDIANA.

C. argillicola.
C. bartonii.
C. blandingii acutus.
C. diogenes.
C. gracilis.
C. immunis.
C. immunis spinirostris.
C. pellucidus.
C. pellucidus testii.
C. propinquus.
C. putnami.
C. rusticus.
C. sloanii.
C. virilis.

INDIAN TERRITORY.

C. blandingii acutus.
C. carolinus.
C. difficilis.
C. palmeri longimanus.
C. virilis.

IOWA.

C. blandingii acutus.
C. diogenes.
C. gracilis.
C. immunis.
C. neglectus.
C. propinquus.
C. rusticus.
C. virilis.

KANSAS.

C. diogenes.
C. gracilis.
C. immunis.
C. immunis spinirostris.
C. nais.
C. neglectus.
C. pilosus.
C. rusticus.
C. simulans.
C. virilis.

KENTUCKY.

C. bartonii.
C. cornutus.
C. diogenes.
C. pellucidus.
C. propinquus.
C. putnami.
C. rusticus.
C. sloanii.

LOUISIANA.

C. argillicola.
C. blandingii acutus.
C. clarkii.
C. diogenes.
C. schufeldtii.

MAINE.

C. bartonii.

MARYLAND.

C. affinis.
C. bartonii.
C. bartonii robustus.
C. blandingii.
C. diogenes.
C. uhleri.

MASSACHUSETTS.

C. bartonii.

MICHIGAN.

C. argillicola.
C. diogenes.
C. immunis.
C. propinquus.
C. rusticus.
C. virilis.

MINNESOTA.

C. diogenes.
C. immunis.
C. virilis.

MISSISSIPPI.

C. argillicola.
C. babatus.
C. blandingii.
C. clarkii.
C. clypeatus.
C. diogenes.
C. hayi.
C. lancifer.
C. latimanus.
C. mississippiensis.

MISSOURI.

C. bartonii.
C. blandingii acutus.
C. diogenes.
C. gracilis.
C. harrisonii.
C. hylas.
C. immunis.
C. medius.
C. neglectus.
C. rusticus.
C. setosus.
C. virilis.

NEBRASKA.

C. immunis.
C. nebrascensis.
C. virilis.

NEW JERSEY.

C. affinis.
C. bartonii.
C. blandingii.
C. diogenes.

NEW MEXICO.

C. simulans.

NEW YORK.

C. affinis.
C. bartonii.
C. bartonii robustus.
C. blandingii.
C. immunis.
C. obscurus.
C. propinquus.
C. virilis.

NORTH CAROLINA.

C. acuminatus.
C. argillicola.
C. bartonii.
C. blandingii.
C. blandingii acutus.
C. carolinus.
C. diogenes.
C. longulus.
C. spinosus.

OHIO.

C. argillicola.
C. bartonii.
C. blandingii acutus.
C. clarkii.
C. diogenes.
C. gracilis.
C. immunis.
C. propinquus.
C. propinquus sanbornii.
C. rusticus.

PENNSYLVANIA.

C. affinis.
C. bartonii.
C. bartonii robustus.
C. carolinus.
C. diogenes.
C. obscurus.
C. propinquus.
C. rusticus.

RHODE ISLAND.

C. bartonii.

SOUTH CAROLINA.

C. acuminatus.
C. barbatus.
C. bartonii.
C. blandingii.
C. blandingii acutus.
C. hagenianus.
C. latimanus.
C. spinosus.
C. troglodytes.

TENNESSEE.

C. bartonii.
C. bartonii longirostris.
C. bartonii robustus.
C. blandingii acutus.
C. carolinus.
C. diogenes.
C. erichsonianus.
C. extraneus.
C. extraneus girardianus.
C. forceps.
C. hamulatus.
C. immunis spinirostris.
C. latimanus.
C. longulus.
C. palmeri.
C. putnami.
C. rusticus.
C. spinosus.
C. virilis.

TEXAS.

C. argillicola.
C. blandingii.
C. blandingii acutus.
C. clarkii.
C. neglectus.
C. palmeri longimanus.
C. rusticus.
C. simulans.
C. virilis.

VERMONT.

C. bartonii.

VIRGINIA.

C. affinis.
C. bartonii.
C. bartonii robustus.
C. blandingii.
C. carolinus.
C. diogenes.
C. forceps.
C. longulus.

WEST VIRGINIA.

C. bartonii.
C. bartonii longirostris.
C. carolinus.
C. longulus.

WISCONSIN.

C. blandingii acutus.
C. diogenes.
C. gracilis.
C. immunis.
C. propinquus.
C. rusticus.
C. stygius.
C. virilis.

WYOMING.

C. diogenes.
C. immunis.
C. virilis.

Mexico.

C. carinatus.
C. chaplanus.
C. digueti.
C. immunis.
C. mexicanus.
C. montezumæ.
C. montezumæ areolatus.
C. montezumæ dugesii.
C. montezumæ occidentalis.
C. wiegmanni.

Cuba.

C. cubensis.

CONCLUSIONS CONCERNING DISTRIBUTION.

While working over the data for the catalogue, I sometimes thought that it might be possible to prepare a list of species which occur in mountain streams, or in the lowlands, but I have been convinced of the wisdom of my intention to make the paper mainly a compilation of data, with very few conclusions. While many minor conclusions have occurred to me, they will not be suggested without more extensive data. In considering the distribution of individuals and species with

reference to local factors, as temperature, purity and rapidity of stream, direct and detailed observations are very scanty, while conclusions as to distribution in the broader sense, the range of species, groups, and the genus itself, are limited by the unexplored condition of much of the territory.

On the subject of distribution of the crayfishes in its ecological phases, very little has appeared. Faxon ('85) observes the occurrence of the same species in the head waters of streams on the opposite side of a watershed, as has been observed in fishes, and gives as examples *C. extraneus* and *C. spinosus* in the upper waters of the Santee, Alabama and Tennessee rivers, and also that the forms of the upper and lower part of a river may be different. As illustrations of this, he gives *C. bartonii*, *C. latimanus*, *C. acuminatus* and *C. spinosus* in the upper portion of the Santee river, while in the lower portion of the same basin live *C. blandingii acutus* and *C. troglodytes*.' Various minor notes have appeared upon the occurrence of different species in different types of localities, but these are for the most part too meager to be considered in a very general summary. The observations will be found under the species concerned. Ganong ('87 and '89) has discussed the distribution of *C. bartonii*, the only species found in New Brunswick. After giving the localities (see catalogue), he says: "The crayfish has probably been introduced into this province by way of the Allegash from the head waters of the Penobscot. 'The St. John and Penobscot are connected by a canal from Telos lake to Webster pond, and the divide between the head waters of the Penobscot and the Kennebec is so low that it is said that in very wet seasons their waters intermingle.' It has probably spread into the Restigouche by way of Grand river, and into the Miramichi by way either of the Nashwaak or of the Shiktehawk or Beccaguimec. Where the sources of these streams are so near each other, and interlock in such a fashion as they do, there would be little difficulty in the animal spreading from one to the other, particularly where the divide is low."

A case of direct observation upon the relative distribution of different species is given by Williamson ('01), who says, under *C. bartonii robustus:* "Observations indicate that this variety occurs in streams in which both *bartonii* and *propinquus* occur, the variety being found in that part of the stream where the

two species are found. A collector starting at the head waters of Squaw Run [37, 1] would find *bartonii;* following the stream, he would soon notice *robustus* among his captures; then an occasional *propinquus*, till finally *bartonii* would become more rare and disappear, and near the mouth of the creek he would find only the species *propinquus*. If the collector chose to follow on down the Alleghany river he would still notice only *propinquus*. After reaching the Ohio, a few specimens from the ripples about Neville island would show him that he had found another species, *rusticus*."

Under the "Summary of Habits" reference was made to the "Conclusions Concerning Distribution" for a discussion of character of localities. Crayfishes are found in varied habitats, from burrows in a prairie which is dry for a large part of the year, stagnant ponds, roadside ditches, and salt marshes, to the pure cold water of mountain springs and streams. The differences between the stream which has reached or nearly reached base level and one which is in a younger stage of its life-history, or between the upper and lower portions of a stream which shows many stages of an ideal life-history, are well known and need not be described here. Certain fishes are known to be typical of each class of locality, and it is safe to assume that the rule will to some extent hold good with the crayfishes as well. For some species it is already known and field observation will doubtless show it to be true of others. It is not advisable to attempt a list of forms at present, but much may be learned in regard to any species by consulting the table of distribution by states and especially by river systems.

One cannot work in the limited literature on the habits and distribution of the different forms without observing that the same species may be recorded as occurring in, or even typical of, very different conditions of environment. As I have pointed out, *C. virilis* is found in small streams, occurring almost exclusively in the rocky, more rapid portions, and being absent in the muddier, slower portions, though it may be found in very muddy streams or even in stagnant ponds with *C. immunis* and *C. gracilis*, where it must have the same habits. *C. bartonii* seems to be characteristic of the cooler, purer mountain springs and streams and is found in caves with *C. pellucidus*, but it is also found associated with *C. diogenes*, and with the same

habits. *C. affinis* has been shown to occur in very different habitats. *C. blandingii* is by no means confined to one type of locality. The species given are sufficient to illustrate the point in question.

The distribution of the fresh-water fishes has been quite carefully worked up, and they have been in a limited way divided into classes according to the character of the habitat.[24] At the present time it is not advisable to attempt to assign the crayfishes to groups in any but a provisional manner, but the available data for any species may be obtained from the tables of distribution and the catalogue. Certain species it is possible to limit quite definitely to some type of locality.

Of species occurring in salt water only one is known: *C. uhleri* is found in salt marshes and also in brackish and fresh water, where *C. blandingii* is sometimes found associated with it. According to Faxon ('85), Lake Tezcoco, where *C. montezumæ* is found, is said to be salt.

The burrowing species obviously have a great advantage over the other forms in distribution, in that they are able to occupy territory which is not available for others except at certain seasons. I may here call attention to their great range of distribution. *C. diogenes* is the most widely distributed species of the genus, occurring in Boulder county, Colorado, at the foot of the Rocky Mountains and southeastern Wyoming on the west, in Minnesota, Wisconsin and Michigan on the north, in New Jersey, Maryland, Virginia, North and South Carolina on the east, and in Mississippi and southern Louisiana on the south. *C. argillicola* is found in Canada on Lake Ontario, in Michigan, Ohio, Illinois, Indiana, North Carolina, Mississippi, Louisiana, and Texas. *C. carolinus*, long known from only the Appalachian region of Virginia, is now known to occur in northeastern Indian Territory and western Pennsylvania. In how far this distribution is to be explained by the habits of the ani-

24. Jordan (Science Sketches) recognizes the following classes of fresh-water fishes:

1. Lowland fishes.
2. Channel fishes.
3. Upland fishes.
4. Mountain fishes.
5. Lake fishes.
6. Anadromous fishes.
7. Catadromous fishes.
8. Brackish-water fishes.

With the sixth and seventh we have nothing to do in the crayfishes. The fifth group is hardly represented, or at least there are as yet very little data to indicate reasons for such a group as Jordan has defined it. Several species have been reported from lakes, but whether from the lake itself or from small tributaries or bays is not known in many cases. *C. stygius* is reported as washed up on the shores of Lake Michigan during a storm. With the first four and the eighth group we may be concerned, but it is impossible at the present time to give a list assigning more than a few of the species to a definite type of locality.

mals it is hardly safe to suggest.[25] Range in altitude as well as in longitude and latitude is to be noticed. Compare the elevation of Boulder, Colo., with lower Louisiana.

The swamp, stagnant-water and lowland species are many, and it is from these that burrowing species may for the most part be supposed to have originated. Without attempting to present a list, attention may be called to the forms found along the Atlantic coast plain and the lower parts of the Gulf States—Florida, Georgia, Alabama, Mississippi, Louisiana, and lower Texas. It is very evident, however, that height above the sea is not the only factor determining lowland conditions, and an examination of the streams and species of the Mississippi valley gives some interesting suggestions.

Data are entirely too meager to say what forms are characteristic of the larger streams. In most of the material reported, data which would make it of value for any such work as this are absent, and very little can be safely concluded from the general locations given. The small tributaries of a stream may be entirely different from the main stream and the species found in them quite different. Until adequate data are secured by collectors and published with catalogues of species little is to be hoped for.

Some species seem to be characteristic of mountain streams, and a comparison of the fauna of the upper Appalachian tributaries of some of the Atlantic and Gulf rivers offers suggestions of interest. *C. extraneus*, *C. spinosus*, *C. bartonii*, *C. acuminatus*, *C. erichsonianus*, *C. forceps*, *C. longulus*, and perhaps several others, seem to be confined to mountain streams.

That the number of species bears no relation to the area drained by the river is well known, and may be illustrated by the following table:

Penobscot, 9000 miles, one species.[26]
Hudson, 13,400 miles, two species.
Potomac, 14,500 miles, seven species.
Cape Fear, 8,400 miles, three species.
Santee, 14,700 miles, six species.
Tennessee, 43,900 miles, twenty-one species.

25. The burrowing species are not so easily collected as are some of the others, and our knowledge of their actual distribution is very imperfect.

26. In comparing the number of species found in different streams or states I have counted varieties as species.

Ohio, 201,700 miles, twenty-seven species.

Arkansas, 185,700 miles, twelve species.

Faxon ('85) says: "The distinction between the species of the upper waters and the lower waters is most marked in rivers that have a heavy fall from their source to their mouth." I have found it interesting to compare the number of species in a stream with its profile. The Mississippi river, exclusive of its tributaries, has a fall of 1462 feet in 2296 miles, and has thirteen species. The Tennessee river, including its principal tributaries, has a fall of 5214 feet in less than half the number of miles, and contains twenty-one species. The Wabash river, in a length of 517 miles, has a fall of 689 feet, and yields twelve species. Of the streams emptying on the south Atlantic coast, the Cape Fear river, with a fall of 130 feet in 172 miles, has three species; the Santee, with its tributaries, a fall of 2658 feet in 479 miles, and six species; the Savannah river, with a length of 314 miles and a fall of 577 feet, three species. Comparing the distribution by states, we find that in the southern United States, where differentiation into species is the greatest, Florida, with a maximum elevation of 328 feet, has five species; Louisiana, reaching a height of 362 feet, has five; Mississippi, 602 feet, has ten; Georgia, ranging from sea-level to over 5000 feet, has fourteen; Alabama, sea-level to 2018 feet, has seventeen species; and Texas, sea-level to nearly 8000 feet, has ten species. The range of elevation can give no idea of the profile of a stream or a state, and the reasons for the differences may be much more clearly seen by a glance at a curve plotting the elevation of the stream at different points. In the examples given a profile will show that there is a very great difference in the amount and relative proportion of the mountain, upland and flood-plain portion of the river in each case. Theoretically, other things being equal, the stream offering the most diverse conditions of environment would be expected to have the greatest number of species, and it is evident that even in a river of considerable length a stream with but a small fall can offer comparatively few conditions, while a stream with a heavy fall during the first part of its course may offer a great number. It is very easy to select from the tables illustrations which do not agree with those here given, and I am perfectly aware that the problem is by no means simple or without complications, but

I think that when proper allowance is made for other factors the suggestion made here of a direct relation between the contour of a stream and the number of its species is a helpful one.

The occurrence of the same species in the head waters of streams on the opposite sides of a watershed has already been referred to. Adams ('01) calls attention to the occurrence of *C. spinosus*, *C. erichsonianus* and *C. extraneus* in the Tennessee river, and also in the head waters of the Coosa-Alabama system, and calls attention to its significance. The occurrence of *C. carolinus*, apparently an upland species, in northeastern Indian Territory, has been noted.[27] Many cases of apparent isolation are doubtless due to our imperfect knowledge of distribution. In several cases I have found instances in which upland species occurred in the lower portion of the stream under conditions which would seem to be quite different from their usual ones. Whether these isolated localities are merely the edge of the range of the species which is to be found under very diverse conditions, or whether its occurrence there is accidental, remains to be seen.

Distribution in its broader sense I shall not consider. Faxon ('85) and Ortmann ('02) have discussed the distribution of the groups and the genus, and have advanced theories for the origin of the genus and its groups. Their theories are somewhat at variance with each other, but space cannot be devoted to a discussion of them here. My object has been to consider the ecological factors, and while some interesting points present themselves in connection with the groups the time is not ripe for their discussion.

27. In this place a statement made by Jordan (Science Sketches) is interesting: "Again, streams of the Ozark mountains, similar in character to the rivers of East Tennessee, have an essentially similar fish fauna, although between the Ozarks and the Cumberland range lies an area of lowland bayous into which such fishes are never known to penetrate. We can, however, imagine that these upland fishes may be sometimes swept down from one side or the other into the Mississippi, from which they might ascend on the other side. But such transfers certainly do not often happen. This is apparent from the fact that the two faunæ are not quite identical, and in some cases the same species are represented by perceptibly different varieties on one side and the other. The time of the commingling of these faunæ is perhaps now past, and it may have occurred only when the character of the intervening region was colder than it is at present."

SUMMARY AND CONCLUSIONS CONCERNING HABITS.

Character of Localities. The character of the waters in which the crayfishes occur has been sufficiently discussed under the conclusions concerning distribution.

Summary of Habits by Groups. As already suggested under "Distribution," the time is not come for any generalizations as to the habits of the groups. The most-modified forms — the blind species and the burrowing species — are not confined to a single group.

Habits During Winter. Of the habits of the crayfishes during the winter little is definitely recorded. It seems most probable that the stream-inhabiting species pass the winter in burrows in the bank or under stones, etc., in the bed of the streams. The latter is sometimes the case with *C. virilis*. The burrowing species seem quite generally to spend the winter in burrows, coming out early in the spring, and returning again when the water begins to become low, as the summer progresses.

The Blind Species. A summary is unnecessary; the information at hand may be found under *C. acherontis*, *C. setosus*, *C. hamulatus*, *C. pellucidus*, and *C. pellucidus testii*.

The Burrowing Species. Some of the North American forms have attracted particular attention on account of a peculiarity in their mode of life as compared with the better-known European species. While the interest which has been taken in the burrowing forms is a perfectly natural one, it seems that in some ways an entirely too difficult problem has been made of it, for the origin of the habit seems quite easy of explanation. *Cambarus* is not the only genus of the family having representatives which depend more or less upon this mode of life, at least at certain seasons of the year, or when being in certain localities,[28] and the ultimate adoption of this method of life as the regular one by some species is not at all difficult to conceive, especially in a territory vast areas of which are habitable for the typical members of the genus for a part of the year only.

28. The burrowing habits of *Cheraps bicarinatus* have been described, and the same habit is characteristic of some members of the South American genus *Parastacus*. (See Faxon, '98, and Lonnberg, '98.) In some localities *Astacus* is said to burrow extensively in the banks of the streams. (See Huxley, '97.)

Under this head are to be placed only the species which show a more special dependence upon this method of life for their ability to live in a given territory. It seems not unreasonable to suppose that most, if not all, the stream-inhabiting species dig short burrows into the banks more or less frequently, at least in certain localities.

The following species are those which seem to be most dependent on the burrowing habit: *C. diogenes*, *C. gracilis*, *C. carolinus*, *C. argillicola*, *C. simulans*, and *C. immunis*.

C. diogenes has well been characterized as preeminently a burrowing species, and, owing to its range of distribution and peculiarities of its habits as compared with other species inhabiting the same localities, more observations have been made on this than any other form. Its presence is usually indicated in the low places, where it is most frequently found by the large number of mud "chimneys," sometimes scattered over many acres, about a foot in height, radiating from some sluggish stream, ditch, brook, or lower, moister portion of the area, the animals being often found at a considerable distance from any permanent body of water. Of the other species, *C. gracilis* seems to be as typically a burrowing species as *C. diogenes*, being generally reported as an inhabitant of prairie regions. Adults are to be found in stagnant ponds only in early spring, only one exception being noted. While the burrows are frequently found a long distance from any permanent water, *C. simulans* has been reported from streams and ponds and from burrows in a slough. *C. immunis* is recorded mostly from stagnant ponds, resorting to burrowing upon the drying up of these. I have never taken it in running streams. For *C. argillicola* and *C. carolinus* the character of the habitat has not been described.

The chimney of *C. diogenes* has a maximum height of one foot, but is usually lower, is circularly pyramidal in shape, often somewhat higher than broad, the most remarkable difference being that of chimneys two inches in diameter and eight to eleven inches in height observed on the sloping side of a ditch, by Abbott, who states that those found in meadows at a distance from running water were invariably broader at the base and not so high as those located near running water. Tarr records exceptional cases where the burrows were in

gravelly ground and the chimneys were, naturally, of the same material, instead of clay, as is usually the case. The description of the exterior of the chimney, composed of irregularly arranged nodules of clay, and the inside a smooth opening of the same diameter as the burrow, is much the same in all the papers. Of the external form of the chimneys of other burrowing species little has been written, but so far as essentials of construction and general appearance are concerned they may be assumed to be very similar.

It would be useless to go into a detailed enumeration of the different forms of burrows described, since, until by more extensive observations than have yet been made the contrary is shown to be the case, the amount of regularity, beyond the necessary similarity of form which characterizes the simple burrows, may not be supposed to be very great. It seems quite evident that the burrows are made as the level of the water lowers, those near the edge having a depth of but a few inches, while those farther back may be some feet deep. A cistern-shaped opening, containing water, is described at the bottom, while enlargements at various intervals in the burrows have been noted and probably correctly explained as the original termini of the burrow which has been projected deeper upon the lowering of the water in the soil, but in the case of the burrows of *C. carolinus*, as observed by Williamson, this interpretation does not seem to hold, and may not in all cases with *C. diogenes* or the other forms. The burrows have usually been described as separate, but when they are very close together they are not unlikely to become connected. The presence of more than one opening to the same burrow in many cases seems established. Sometimes one and sometimes two individuals are found in a burrow.

The purpose and method of construction of the "chimney," as it has been aptly called, have called forth considerable discussion, some maintaining that a structure of such regularity of construction must have some purpose; others concluding that the building of a chimney simply represents the safest and most convenient method of disposing of the material obtained in excavating the burrow. The latter view seems to have by far the greater amount of evidence in its favor. The purpose of sealing the burrows needs more study. The method by

which it is accomplished seems to be simply the filling in of the opening, necessarily kept till the last, through the chimney, with material brought from below. That it is brought from below, and that the sealing is not merely the result of an accidental contraction of the upper part of the chimney when in a moist condition, is shown by the fact that in the case of some chimneys (of *C. diogenes?*) examined the opening was filled with clay of a different color from that of the surface soil or that composing the remainder of the chimney. The process of building the chimney has been described from actual observation only once—by Abbott.

Concerning the purpose of the burrowing there can now be no question, enabling the animal, as it does, to occupy territory otherwise uninhabitable. Some species of the genus appear never to resort to the habit in its limited interpretation, while others, *C. immunis*, and to a less extent *C. virilis*, for example, are inhabitants of ponds or streams and resort to burrowing upon the drying up of the pond or the approach of winter, while *C. diogenes* and *C. gracilis* have adopted this mode of life almost entirely, being found in the open water during but a very small part of the year. That the burrows are not for retreats while the eggs are being hatched has been clearly shown. That they serve as a place of protection against enemies has been suggested. While this cannot be the primary purpose for which they are formed, it may be that the burrowing species suffer less from animal enemies than do some others. My impression is that the percentage of mutilation in *C. gracilis* is less than in *C. immunis* or *C. virilis*, which do not spend so much time in burrows. Burrows are almost invariably described as extending to the water in the soil,[29] and while the water is often very muddy, it enables the animal to keep its gills moist, and this seems to be all that is necessary. There are observations to indicate that in the burrows the animals do not spend all the time in the water at the bottom, but are apt to be found above it.[30] The securing of food is a question which has not been

29. I am told that travelers on the plains watch for the crayfish chimneys as the best indication of a suitable locality in which to dig for water.

30. It is by no means necessary for the crayfish to spend all the time in water. Some of the burrowing species have sometimes been reported as making long excursions overland. *C. blandingii* was taken in a log at a considerable distance from water. *Astacus* is said to make short excursions inland sometimes. I have never been so fortunate as to observe crayfishes climbing trees to escape the rising water, as they were reported by Mr. Holder as doing!

Of *Parastacus hosxleri*, Lonuberg ('98) says: "The sides of the carapace covering the branchial chambers are beset with numerous setæ, each implanted at the anterior margin of a

satisfactorily solved, but the observations have indicated that the species are nocturnal in their habits, and in some cases may leave the burrows and forage for food, or wait at the mouth for anything that may come within reach. That the animals may live for long periods with but little food is known.

In addition to the above-mentioned species, besides the burrowing in the banks or bed of the streams, as has been noted for *C. bartonii*, *C. propinquus*, and *C. sloanii*, there are doubtless others which burrow extensively when conditions demand it. Lonnberg sometimes found *C. fallax* and *C. alleni* "digging holes on the shore at low water." Schufeldt figures the chimney of *C. bartonii robustus; C. virilis* is reported almost exclusively from streams and lakes, but has sometimes been found with *C. immunis*, almost exclusively a stagnant-pond species, and when in such localities it must burrow, as do forms characteristic of such localities. Faxon reports *C. blandingii* from Texas with the label name of "burrowing crab," a fact which is suggestive at least.

From the data now at hand, it certainly seems safe to conclude that the burrowing habit has been adopted as a means of living through an unfavorable period, and that in some species this method of life has been adopted as the almost exclusive one, while all the other advantages of this habit of life, if there are any, are entirely secondary.[31] The burrowing species are to be regarded as the most specialized of the genus.

Exuviation. On the process itself nothing of particular value has appeared, and even if observations were complete,

granule, and between these granules a large number of tiny grooves are seen. The posterior margin of the cervical groove is armed with a dense row of setæ. (See fig. 1.) It seems probable that these features stand in connection with some biological peculiarities of these crayfishes. The structure of the carapace on the branchial chamber seems to be apt to retain the humidity longer on this place than if it were smooth, and this might be of use if the crayfishes should make any excursions on dry land. The inner surface of the carapace covering the branchial chamber is also very densely hairy, which would also serve the same purpose—to retain the water. The armature of the cervical groove would help to carry water (rain?) from the back to the anterior branchial opening along the cervical groove." Of *C. alleni* and *C. fallax*, which he sometimes found burrowing at considerable distance from water, he says: "The inner side of the carapace covering the branchial chamber of these *Cambari* was also very hairy; so this adaptation seems to be common to several crayfishes with similar habits." Whether the structure of the branchial chamber is to be interpreted as has been done by Lonnberg is open to doubt. Neither of the species of *Cambarus* to which he refers is known to be typical burrowing species, and, while I have satisfied myself of the hairiness of the branchiostegite of *C. gracilis* and *C. immunis*, I am not convinced that it is any more so than in forms which do not live under the same conditions, and, in case the adaptation is of the nature suggested, this would be supposed to be the case. The function suggested for the cervical groove requires no comment.

31. This conclusion is supported by what is known concerning the behavior of the burrowing species of other genera of the Astacidæ. The habits of *Parastacus*, as described by Faxon ('98) and Lonnberg ('98) seem very similar to those of certain species of *Cambarus*, and indicate an extension of the territory habitable by the species, just as we find in *C. diogenes*, *C. gracilis*, *C. immunis*, and others. The similarity of habits of *Cherax bicarinatus* and its adaptation to life under very adverse conditions of environment are well seen from the description of its habits as quoted by Faxon ('98).

they would hardly find their proper place in an ecological paper. With the frequency and time of the occurrence, however, we are concerned. The rate of growth and frequency of exuviation in the developing *Cambarus* has not been so carefully observed as in *Astacus*, and the few notes which have been made are not of a character to justify any conclusions. As to the time of exuviation in older individuals we know a little more. According to Putnam, a female of *C. pellucidus*, about two and one-half inches in length, exuviated twice in a period of three months, January 28 to April 20, but another specimen (male or female?) of the same lot, taken in November, had been kept nearly ten months without shedding. Hargitt ('90) took animals of *C. diogenes* (?) and *C. gracilis* (?) which had recently exuviated, and also casts in the streams only in early spring. Never finding animals which had recently shed in the open water, Harris ('00) concludes that individuals of *C. gracilis* must exuviate in their burrows. For the observations on the exuviation of *C. immunis* and *C. virilis*, see the section on "Dimorphism," where it is considered in connection with the alternation of forms.

Breeding Habits. Data concerning the reproduction of any group of animals are admitted to be of the greatest importance. While observations are not extensive in the genus under consideration some interesting points are recorded. Some of the suggestions made by observers are based on such scanty data that they are ignored here.

The observations on conjugation need not be summarized here, since they have been so concisely stated by Mr. Andrews, the only one who has published on this subject.

The carrying of the eggs and young by the female parent need not be considered in this place.

In *C. diogenes*, the habits of which have attracted the attention of more observers than those of any other species, conjugation and the laying of eggs seem to take place in the spring. Girard ('52) found the females in the burrows carrying eggs in March and April. Tarr ('84) gives the middle of May as the approximate time of the hatching of the eggs. Hargitt ('90) observed *C. obesus* and *C. gracilis* kept in aquaria conjugating in the spring. He never found crayfishes (sp.?) mating except in March, April, and sometimes May, and in only two in-

stances was he able to get reports of females "in berry" later than June, and then but a single individual in each case. Hay reports *C. diogenes* as in copulation in the open water April 2, eggs being laid from April 18 to 30. Harris ('02) reports a female with eggs in a not very late stage of development May 3. The taking of a female with eggs nearly ready to hatch on New Year's day, as recorded by Bundy ('77), forms an interesting exception to the above observations and suggests the laying of eggs in the fall, as has been observed in other species. The occurrence of a single individual or of a male and female in a burrow, as has been recorded by different observers, requires careful observation before any significance at all can be attribted to it in this connection. The suggestion which has been made that the burrow is designed as a retreat for the female while the eggs are hatching is no longer tenable, but that much of the period of development may be passed in the burrow is also beyond doubt.

Harris ('00 and '02) finds *C. gracilis* with a *few* young, about old enough to leave the parent, in the open ponds in early spring, and suggests that those with no young must have lost them before or immediately upon leaving the burrows in the spring. The most of the process of hatching must take place in the burrows. Hargitt ('90) noticed crayfish (*C. gracilis ?*) copulating in aquaria in the spring.

In *C. simulans*, another of the burrowing species, Harris ('02) reports females taken from burrows late in August with eggs apparently recently laid. Mrs. Cockerell states that *C. gallinas* (or *C. simulans*) taken in May had the swimmerets loaded with eggs. The differences in time are certainly interesting.

C. immunis is found in the open ponds with eggs, in the fall, and the females appear in the ponds, where the hatching of the eggs is completed, early in the spring—about March 21.

Hay ('96) reports *C. argillicola* with young as early as April 2.

Harris ('02) records *C. neglectus* with eggs and young in early June in the cold water at the mouth of a large cave in the Ozarks, and attributes the absence of eggs or young on other specimens taken in the region to the low temperature of the water at the mouth of the cave, which would retard the hatching of the eggs. Under *C. virilis* (15, ? 27) is noted a specimen, which may be *C. neglectus*, with eggs April 13.

In *C. virilis* eggs are laid in the spring, none being found on females taken during the winter. The ovarian eggs of specimens taken in January seem, so far as may be seen from a rough examination, to be fully developed.

In connection with a discussion of the breeding habits, it may be well to bring together a few observations which have been made on the habits of the young after leaving the parent.

Abbott ('73) says, in speaking of *C. affinis*, *C. acutus*, and *C. bartonii*: "The young *Cambari*, in September, seem to be fully as active as the adults, but do not frequent any given class of localities, as they wander about the beds of streams, creeping forward in a slow, awkward manner, and swimming backwards, when disturbed, with wonderful rapidity."

Williamson ('01) notes the presence of forty-seven young, varying from three-fourths to one and one-eighth inches in length, in a burrow with an adult female of *C. carolinus* on September 24. Young animals about one inch in length were taken in the small pool of water where the adults of *C. simulans* reported by Harris ('02) were taken in burrows.

Harris ('00) notes the occurrence of numbers of young crayfish, apparently *C. gracilis*, in stagnant ponds, where he had noticed young in the spring of the year, about October 20 to November 20, appearing in great numbers at about the time the adults of *C. immunis* disappeared. They were about three-fourths to seven-eighths of an inch in length. About the 1st of March of the next year they appeared before the adults, and although a few days later the pond froze over they were still to be found apparently as plentiful as ever beneath a layer of ice an inch thick. By the 1st of May they had attained a length of from one to one and one-half inches, while May 9 many small animals about five-eighths of an inch in length were observed. These were probably the young of *C. gracilis*, which are carried by the female as late as March 27. It seems, then, that young and adult *C. gracilis* appear in the ponds early in the spring and that the young again appear in the fall after the other species have gone to their burrows.

Abbott ('84) has called attention to the neatness of the chimneys constructed by the small individuals of *C. diogenes*. I have noticed the same thing in *C. gracilis* and *C. immunis* (?). As he suggests, it may have some significance.

REFERENCES TO STREAMS FROM WHICH CRAYFISH HAVE BEEN REPORTED.

I have had occasion to consult considerable literature concerned with the distribution of fresh-water forms—almost exclusively fishes—and have indexed much of what I have examined. The following list includes references to streams from which crayfish have been reported, and while almost none of them are concerned with crayfish they treat of the character of the stream or the distribution of other fresh-water organims. The list makes no pretense of completeness, but is an index to some suggestive literature, and will, I trust, prove helpful.

Alabama River:
Adams.—Am. Nat., vol. 35, pp. 845, 846, 847. 1901.
Faxon.—Rev. Astac., p. 173.
Jordan.—Am. Nat., vol. 11, pp. 608, 610, 612. 1877.
Jordan.—Bull. U. S. Nat. Mus., No. 12, pp. 91, 93. 1878.
Simpson.—Sci., N. S., vol. 12, pp. 133, 134, 135. 1900.

Alleghany River:
Cope.—Journ. Acad. Nat. Sci. Phila., ser. 2, vol. 6, p. 241. 1869.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 44. 1901.

Altamaha River:
Faxon.—Rev. Astac., p. 173.
Jordan.—Bull. U. S. Nat. Mus., No. 12, p. 91. 1878.

Androscoggin River:
Faxon.—Rev. Astac., p. 173.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 10. 1901.

Apalachicola and Chattahoochee Rivers:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 30. 1901.

Arkansas River:
Evermann and Kendall.—Bull. U. S. F. C., vol. 12, pp. 61–65. 1892.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 63–65. 1901.
Jordan and Gilbert.—Proc. U. S. Nat. Mus., vol. 9, p. 6. 1886.
Jordan.—Sci. Sketches, pp. 111, 113. 1888.
Meek.—Bull. U. S. F. C., vol. 14, pp. 69, 83, 86. 1894.

Big Nance Creek:
Gilbert.—Bull. U. S. F. C., vol. 9, p. 444. 1889.

Big Pigeon River:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 53. 1901.

Black River:
Meek.—Bull. U. S. F. C., vol. 14, p. 74. 1894.

Blackstone River:
Faxon.—Rev. Astac., p. 173.

Black Warrior River:
Adams.—Am. Nat., vol. 35, p. 845. 1901.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 32.
Gilbert.—Bull. U. S. F. C., vol. 9, p. 145. 1889.
Simpson.—Sci., N. S., vol. 12, pp. 134, 135. 1900.
Blackwater River:
Jordan.—Bull. U. S. F. C., vol. 8, p. 118. 1888.
Blue River:
Kirsch.—Bull. U. S. F. C., vol. 14, p. 33. 1894.
Boyer River:
Meek.—Bull. U. S. F. C., vol. 10, p. 248. 1890.
Brazos River:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 33, 34. 1901.
Jordan.—Sci. Sketches, p. 113. 1888.
Broad River:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 27. 1901.
Jordan.—Bull. U. S. F. C., vol. 8, p. 135. 1888.
Bull Creek:
Woolman.—Bull. U. S. F. C., vol. 10, p. 276. 1890.
Cahawba River:
Gilbert.—Bull. U. S. F. C., vol. 9, p. 145. 1889.
Simpson.—Sci., N. S., vol. 12, p. 135. 1900.
Canadian River:
Evermann and Kendall.—Bull. U. S. F. C., vol. 12, pp. 61–65. 1892.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 65, 66. 1901. (See, also, Cimarron river.)
Cape Fear River:
Faxon.—Rev. Astac., p. 173.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 25. 1901.
Jordan.—Bull. U. S. F. C., vol. 8, pp. 131–133, 135. 1888.
Catawba River:
Adams.—Am. Nat., vol. 35, p. 845. 1901.
Jordan.—Am. Nat., vol. 11, p. 608. 1877.
Jordan.—Bull. U. S. Nat. Mus., No. 12, p. 91. 1878.
Jordan.—Bull. U. S. F. C., vol. 8, pp. 135, 136. 1888.
Jordan.—Sci. Sketches, p. 123. 1888.
Cedar River:
Meek.—Bull. U. S. F. C., vol. 10, pp. 230, 231. 1890.
Lake Champlain:
Faxon.—Rev. Astac., p. 174.
Jordan.—Am. Nat., vol. 11, p. 611. 1877.
Jordan.—Bull. U. S. Nat. Mus., No. 12, p. 94. 1878.
Jordan.—Sci. Sketches, p. 110. 1888.
Chattahoochee River:
Adams.—Am. Nat., vol. 35, p. 845. 1901.
Faxon.—Rev. Astac., p. 173.
Hays and Campbell.—Sci., n. s., vol. 12, pp. 131, 132. 1900.
Jordan.—Am. Nat., vol. 11, pp. 608, 610. 1877.
Jordan.—Bull. U. S. Nat. Mus., No. 12, pp. 91, 93. 1878.
Jordan.—Sci. Sketches, pp. 122, 123. 1888.
Simpson.—Sci., n. s., vol. 12, pp. 134, 135. 1900.

CHESAPEAKE BAY:

Faxon.—Rev. Astac., p. 173.

CHOWAN RIVER:

Jordan.—Bull. U. S. F. C., vol. 8, pp. 118–120. 1888.

CIMARRON RIVER:

Mr. C. D. Bunker, of Oklahoma University, writes me: "The Cimarron, Canadian and Red rivers are wide sand flats, with only narrow channels of water, and the Canadian is dry most of the year, the banks are sand, and it is a rare thing to find a crayfish burrow, and rarer still to find a crayfish in the water."

CLINCH RIVER:

Cope.—Journ. Acad. Nat. Sci. Phila., ser. 2, vol. 6, p. 239. 1869.

Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 55. 1901.

Jordan.—Am. Nat., vol. 11, p. 612. 1877.

Jordan.—Bull. U. S. Nat. Mus., No. 12, p. 95. 1878.

CONGAREE RIVER:

Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 27. 1901.

COOSA RIVER:

Adams.—Am. Nat., vol. 35, pp. 844, 846, 847, 848, 849. 1901.

Faxon.—Rev. Astac., p. 173.

Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 30, 31. 1901.

Gilbert.—Bull. U. S. F. C., vol. 9, p. 145. 1889.

Hays and Campbell.—Sci., n. s., vol. 12, pp. 131, 133. 1900.

Simpson.—Sci., n. s., vol. 12, pp. 134, 135. 1900.

CUMBERLAND RIVER:

Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 55–57. 1901.

Jordan.—Am. Nat., vol. 11, pp. 612, 613. 1877.

Jordan.—Bull. U. S. Nat. Mus., No. 12, p. 95. 1878.

Jordan.—Sci. Sketches, p. 114. 1888.

Kirsch.—Bull. U. S. F. C., vol. 11, pp. 259–270. 1891.

Woolman.—Bull. U. S. F. C., vol. 10, pp. 263–268. 1890.

CYPRESS CREEK:

Meek.—Bull. U. S. F. C., vol. 9, p. 144. 1889.

DELAWARE RIVER:

Cope.—Journ. Acad. Nat. Sci. Phila., ser. 2, vol. 6, p. 247. 1869.

Faxon.—Rev. Astac., p. 173.

Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 15, 16. 1901.

Jordan.—Am. Nat., vol. 11, p. 610. 1877.

Jordan.—Bull. U. S. Nat. Mus., No. 12, p. 93. 1878.

DES MOINES RIVER:

Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 78. 1901.

Meek.—Bull. U. S. F. C., vol. 10, pp. 222–225. 1890.

LAKE DRUMMOND:

Jordan.—Bull. U. S. F. C., vol. 8, p. 114. 1888.

LAKE ERIE:

Faxon.—Rev. Astac., p. 174.

Jordan.—Am. Nat., vol. 11, pp. 611, 612. 1877.

Jordan.—Bull. U. S. Nat. Mus., No. 12, pp. 94, 95. 1878.

Jordan.—Sci. Sketches, p. 127. 1888.

ESCAMBIA RIVER:
Gilbert.—Bull. U. S. F. C., vol. 9, pp. 145, 146. 1889.

ETOWAH RIVER:
Faxon.—Rev. Astac., p. 173.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 31. 1901.
Hays and Campbell.—Sci., n. s., vol. 12, pp. 131, 132, 133. 1900.

FRENCH BROAD RIVER:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 52. 1901.
Jordan.—Sci. Sketches, p. 112. 1888.

GREEN RIVER:
Woolman.—Bull. U. S. F. C., vol. 10, pp. 252–260. 1890.

GUADALUPE RIVER:
Evermann.—Bull. U. S. F. C., vol. 11, p. 72. Crayfish found in considerable numbers. 1891.
Evermann and Kendall.—Bull. U. S. F. C., vol. 12, pp. 62–65. 1892.
Jordan and Gilbert.—Proc. U. S. Nat. Mus., vol. 9, p. 23. 1886.

HICKORY CREEK:
Meek.—Bull. U. S. F. C., vol. 9, p. 126. 1889.
Meek.—Bull. U. S. F. C., vol. 10, p. 243. 1890.

HOLSTON RIVER:
Cope.—Journ. Acad. Nat. Sci. Phila., ser. 2, vol. 6, pp. 209, 239, 240, 241, 242, 244. 1869.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 54, 55. 1901.
Jordan.—Sci. Sketches, pp. 90, 112. 1888.

HOUSATONIC RIVER:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 13, 14. 1901.
Jordan.—Sci. Sketches, p. 116. 1888.

HUDSON BAY:
Faxon.—Rev. Astac., p. 174.

HUDSON RIVER:
Cope.—Journ. Acad. Nat. Sci. Phila., ser. 2, vol. 6, pp. 208, 247. 1869.
Faxon.—Rev. Astac., p. 173.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 14. 1901.

ILLINOIS RIVER:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 60. 1901.
Jordan.—Am. Nat., vol. 11, pp. 609, 613. 1877.
Jordan.—Bull. U. S. Nat. Mus., No. 12, pp. 92, 95. 1878.
Jordan.—Sci. Sketches, p. 127. 1888.
Meek.—Bull. U. S. F. C., vol. 14, pp. 83, 86. 1894.
Dr. J. W. Beede writes: "In its lower course, the Illinois is an extremely clear, deep stream, with coarse chert gravel bottom, with narrow to wide, flat, sometimes almost swampy, flood plain. It is full of fine fish. The less swift parts are full of a coarse green plant with circlets of leaves." [Cerotophyllum?]

INDIAN CREEK:
Meek.—Bull. U. S. F. C., vol. 10, p. 231. 1890.

IOWA RIVER:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 79. 1901.
Meek.—Bull. U. S. F. C., vol. 10, pp. 227–229, 244. 1890.

James River (Mo.):
Meek.—Bull. U. S. F. C., vol. 9, pp. 124, 128. 1889.

James River (Va.):
Cope.—Journ. Acad. Nat. Sci. Phila., ser. 2, vol. 6, pp. 208, 209, 240, 241, 242, 246. 1869.
Faxon.—Rev. Astac., p. 173.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 22, 23. 1901.
Jordan.—Am. Nat., vol. 11, pp. 612, 613. 1877.
Jordan.—Bull. U. S. Nat. Mus., No. 12, p. 95. 1878.
Jordan.—Bull. U. S. F. C., vol. 8, pp. 107–113. 1888.
Jordan.—Sci. Sketches, pp. 90, 123. 1888.

Johns River:
Jordan.—Bull. U. S. F. C., vol. 8, p. 135. 1888.

Juniata River:
Gannett.—Water Supp. and Papers, U. S. G. Surv., No. 44, p. 19. 1901.

Kanawha River:
Cope.—Journ. Acad. Nat. Sci. Phila., ser. 2, vol. 6, pp. 209, 240, 241, 242, 243, 244, 245, 246. 1869.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 46, 47, 49. 1901.
Jordan.—Sci. Sketches, p. 90. 1888.

Kansas River:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 72, 73. 1901.

Kennebec River:
Faxon.—Rev. Astac. p. 173.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 9. 1901.

Kentucky River:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 57, 58. 1901.
Jordan.—Am. Nat., vol. 11, pp. 611, 612. 1877.
Jordan.—Bull. U. S. Nat. Mus., No. 12, pp. 91, 95. 1878.
Woolman.—Bull. U. S. F. C., vol. 10, pp. 275–281. 1890.

Kiamichi River:
Meek.—Bull. U. S. F. C., vol. 15, p. 341. 1895.

Lizard Creek:
Meek.—Bull. U. S. F. C., vol. 10, p. 222. 1890.

Maumee River:
Jordan.—Am. Nat., vol. 11, p. 609. 1877.
Jordan.—Bull. U. S. Nat. Mus., No. 12, p. 92. 1878.
Kirsch.—Bull. U. S. F. C., vol. 14, pp. 315–337. 1894.

Meramec River:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 68. 1901.
Meek.—Bull. U. S. F. C., vol. 9, p. 116. 1889.

Miami River:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 60. 1901.
Jordan.—Am. Nat., vol. 11, p. 611. 1877.
Jordan.—Bull. U. S. Nat. Mus., No. 12, p. 91. 1878.

LAKE MICHIGAN:
Faxon.—Rev. Astac., p. 174.
Jordan.—Bull. U. S. Nat. Mus., No. 12, p. 94. 1878.
Jordan.—Sci. Sketches, pp. 111, 127. 1888.

MILL CREEK (KAN.):
Dr. J. W. Beede writes me: "Mill creek is in the Flint Hills. Most of the course of the larger part of the stream is very muddy in the channel, with strong ripples occasionally. It is a great deal like the Wakarusa—strikingly so."

MINNESOTA RIVER:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 79, 80. 1901.

MISSISSIPPI RIVER:
Adams.—Am. Nat., vol. 35, pp. 848, 849. 1901.
Cope.—Journ. Acad. Nat. Sci. Phila., ser. 2, vol. 6, p. 246. 1869.
Eigenmann.—Bull. U. S. F. C., vol. 14, pp. 101, 121. 1894.
Faxon.—Rev. Astac., pp. 173, 174.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 38–40. 1901.
Jordan.—Am. Nat., vol. 11, pp. 612, 613. 1877.
Jordan.—Bull. U. S. Nat. Mus., No. 12, p. 95. 1878.
Jordan.—Sci. Sketches, pp. 110, 115, 130. 1888.
Meek.—Bull. U. S. F. C., vol. 10, p. 220. 1890.
Simpson.—Sci., N. S., vol. 12, pp. 133, 134. 1900.

MISSOURI RIVER:
Cope.—Journ. Acad. Nat. Sci. Phila., ser. 2, vol. 6, p. 246. 1869.
Eigenmann.—Bull. U. S. F. C., vol. 14, pp. 101, 102, 106, 120. 1894.
Faxon.—Rev. Astac., p. 174.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 68–70. 1901.
Jordan.—Am. Nat., vol. 11, p. 608. 1877.
Jordan.—Sci. Sketches, p. 113. 1888.
Meek.—Bull. U. S. F. C., vol. 10, p. 245. 1890.

NEOSHO RIVER:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 66. 1901.

NEUSE RIVER:
Faxon.—Rev. Astac., p. 173.
Jordan.—Am. Nat., vol. 11, p. 610. 1877.
Jordan.—Bull. U. S. Nat. Mus., No. 12, p. 93. 1878.
Jordan.—Bull. U. S. F. C., vol. 8, pp. 127–131. 1888.
Jordan.—Sci. Sketches, p. 123. 1888.

NORTH RIVER:
Jordan.—Bull. U. S. F. C., vol. 8, pp. 108, 109. 1888.

OCONEE RIVER:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 29. 1901.

OHIO RIVER:
Adams.—Am. Nat., vol. 35, p. 846. 1901.
Cope.—Journ. Acad. Nat. Sci. Phila., ser 2, vol. 6, p. 247. 1869.
Faxon.—Rev. Astac., p. 174.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 41–43. 1901.

Ohio River—*continued:*
Jordan.—Am. Nat., vol. 11, pp. 612, 613. 1877.
Jordan.—Bull. U. S. Nat. Mus., No. 12, p. 95. 1878.
Jordan and Gilbert.—Proc. U. S. Nat. Mus., vol. 9, p. 25. 1886.
Jordan.—Sci. Sketches, pp. 114, 121, 126. 1888.
Simpson.—Sci., N. S., vol. 12, p.134. 1900.

Lake Ontario:
Faxon.—Rev. Astac., p. 174.
Jordan.—Bull. U. S. Nat. Mus., No. 12, p. 94. 1878.
Smith.—Bull. U. S. F. C., vol. 10, pp. 178, 179. 1890.

Osage River:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 72. 1901.

Ouachita River:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 62, 63. 1901.
Jordan.—Sci. Sketches, p. 114. 1888.
Jordan and Gilbert.—Proc. U. S. Nat. Mus., vol. 9, pp. 9, 25. 1886.
Meek.—Bull. U. S. F. C., vol. 9, p. 137. 1889.
Meek.—Bull. U. S. F. C., vol. 14, p. 69. 1894.

Passaic River:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 15. 1901.

Peace River:
Woolman.—Bull. U. S. F. C., vol. 10, pp. 295–297. 1890.

Pecos River:
Evermann and Kendall.—Bull. U. S. F. C., vol. 12, pp. 64, 65. 1892.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 37. 1901.

Penobscot River:
Faxon.—Rev. Astac., p. 173.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 9. 1901.

Platte River:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 74–76. 1901.
Meek.—Bull. U. S. F. C., vol. 14, p. 135. 1894.

Potomac River:
Faxon.—Rev. Astac., p. 173.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 20, 21. 1901.
Jordan.—Am. Nat., vol. 11, pp. 608, 612, 613. 1877.
Jordan.—Bull. U. S. Nat. Mus., No. 12, p. 95. 1878.
Jordan.—Bull. U. S. F. C., vol. 8, pp. 101–107. 1888.
Jordan.—Sci. Sketches, p. 122. 1888.

Powell River:
Cope.—Journ. Acad. Nat. Sci. Phila., ser. 2, vol. 6, p. 239. 1869.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 55. 1901.
Jordan.—Am. Nat., vol. 11, p. 609. 1877.
Jordan.—Bull. U. S. Nat. Mus., No. 12, p. 92. 1878.
Woolman.—Bull. U. S. F. C., vol. 10, p. 269. Crayfish noticed to be abundant. 1890.

Rappahannock River:
Faxon.—Rev. Astac., p. 173.

RED RIVER:
Evermann and Kendall.—Bull. U. S. F. C., vol. 12, pp. 61–65. 1892.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 61, 62, 80. 1901.
Jordan and Gilbert.—Proc. U. S. Nat. Mus., vol. 9, p. 13, 1886.
Jordan.—Sci. Sketches, pp. 111, 113. 1888.
Meek.—Bull. U. S. F. C., vol. 14, pp. 69, 70. 1894.
Meek.—Bull. U. S. F. C., vol. 15, p. 341. 1895.
See, also, Cimarron river.

RED RIVER OF THE NORTH:
Eigenmann.—Bull. U. S. F. C., vol. 14, pp. 101, 102, 103, 120. 1894.
Jordan.—Bull. U. S. Nat. Mus., No. 12, p. 91. 1878.

REEDY FORK, CAPE FEAR RIVER:
Jordan.—Bull. U. S. F. C., vol. 8, p. 131. 1888.

REPUBLICAN RIVER:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 73. 1901.

RIO GRANDE RIVER:
Evermann and Kendall.—Bull. U. S. F. C., vol. 12, pp. 61–65. 1892.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, pp. 36, 37. 1901.
Jordan.—Sci. Sketches, p. 109. 1888.

ROANOKE RIVER:
Collins and Smith.—Bull. U. S. F. C., vol. 11, pp. 197–200. 1891.
Cope.—Journ. Acad. Nat. Sci. Phila., ser. 2, vol. 6, pp. 209, 240, 241, 242, 243. 1869.
Faxon.—Rev. Astac., p. 173.
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 23, 24. 1901.
Jordan.—Am. Nat., vol. 11, pp. 611, 613. 1877.
Jordan.—Bull. U. S. Nat. Mus., No. 12, p. 98. 1878.
Jordan.—Bull. U. S. F. C., vol. 8, pp. 120–124, 131. 1888.
Jordan.—Sci. Sketches, p. 90. 1888.

ROCK CREEK:
Kirsch.—Bull. U. S. F. C., vol. 11, p. 267. 1891.

SACO RIVER:
Faxon.—Rev. Astac., p. 173.

SALT RIVER (KY.):
Woolman.—Bull. U. S. F. C., vol. 10, pp. 250, 251. 1890.

SALUDA RIVER:
Gannett.—Water Supp. and Irr. Papers, U. S. G. Surv., No. 44, p. 27. 1901.
Jordan.—Am. Nat., vol. 11, p. 608. 1877.
Jordan.—Bull. U. S. Nat. Mus., No. 12, p. 91. 1878.
Jordan.—Bull. U. S. F. C., vol. 8, p. 135. 1888.

SAN ANTONIO RIVER:
Evermann.—Bull. U. S. F. C., vol. 11, pp. 71, 72. Crayfish reported as abundant. 1891.
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C. meekii 60, 108, 138
C. mexicanus 58, 108, 151
C. mississippiensis 59, 108, 138, 151
C. montezumæ 60, 108, 151, 158
C. montezumæ areolatus 60, 108, 151
C. montezumæ dugesii 60, 108, 151
C. montezumæ occidentalis 60, 108, 151
C. nais 59, 109, 138
C. nebrascensis 109, 151
C. neglectus 59, 109–111, 138, 168
C. obscurus 112, 138
C. palmeri 59, 112, 138
C. palmeri longimanus 59, 112, 138
C. pellucidus 58, 67, 77, 112–118, 151, 157, 162, 167
C. pellucidus testii 58, 112–118, 151, 162
C. penicillatus 118
C. pilosus 59, 118–119, 138
C. propinquus 59, 61, 62, 63, 116, 119–121, 123, 138, 151, 156, 157, 166

C. propinquus sanbornii 59, 120–121, 138
C. pubescens 58, 121, 138
C. putnami 60, 121, 138
C. rusticus 60, 110, 121–123, 138, 151, 157
C. schufeldtii 60, 126, 138
C. setosus 59, 123–126, 138, 162
C. simulans 58, 126–129, 138, 163, 168, 169
C. sloanii 59, 77, 129, 138, 151, 166
C. spiculifer 58, 130, 138
C. spinosus 60, 130, 138, 156, 159, 161
C. stygius 130, 138
C. troglodytes 58, 130, 138, 151, 156
C. typholobius 131, 151
C. uhleri 59, 131, 138, 158
C. versutus 58, 131, 138
C. virilis 59, 64, 99, 103, 131–135, 138, 151, 162, 165, 166, 167, 168, 169
C. wiegmanni 58, 135, 138, 151, 157

PLATE I.

Conjugation of *Cambarus affinis*, from photograph by Dr. R. W. Shufeldt.

PLATE I.

See page 67.

PLATE II.

Distribution of *Cambarus virilis*.

PLATE II.

PLATE III.

Distribution of *Cambarus*.

FIG. 1.—*C. affinis.*
FIG. 2.—*C. argillicola.*
FIG. 3.—*C. bartonii*, *C. bartonii longirostris*, and *C. bartonii robustus.*
FIG. 4.—*C. blandingii.*

PLATE III.

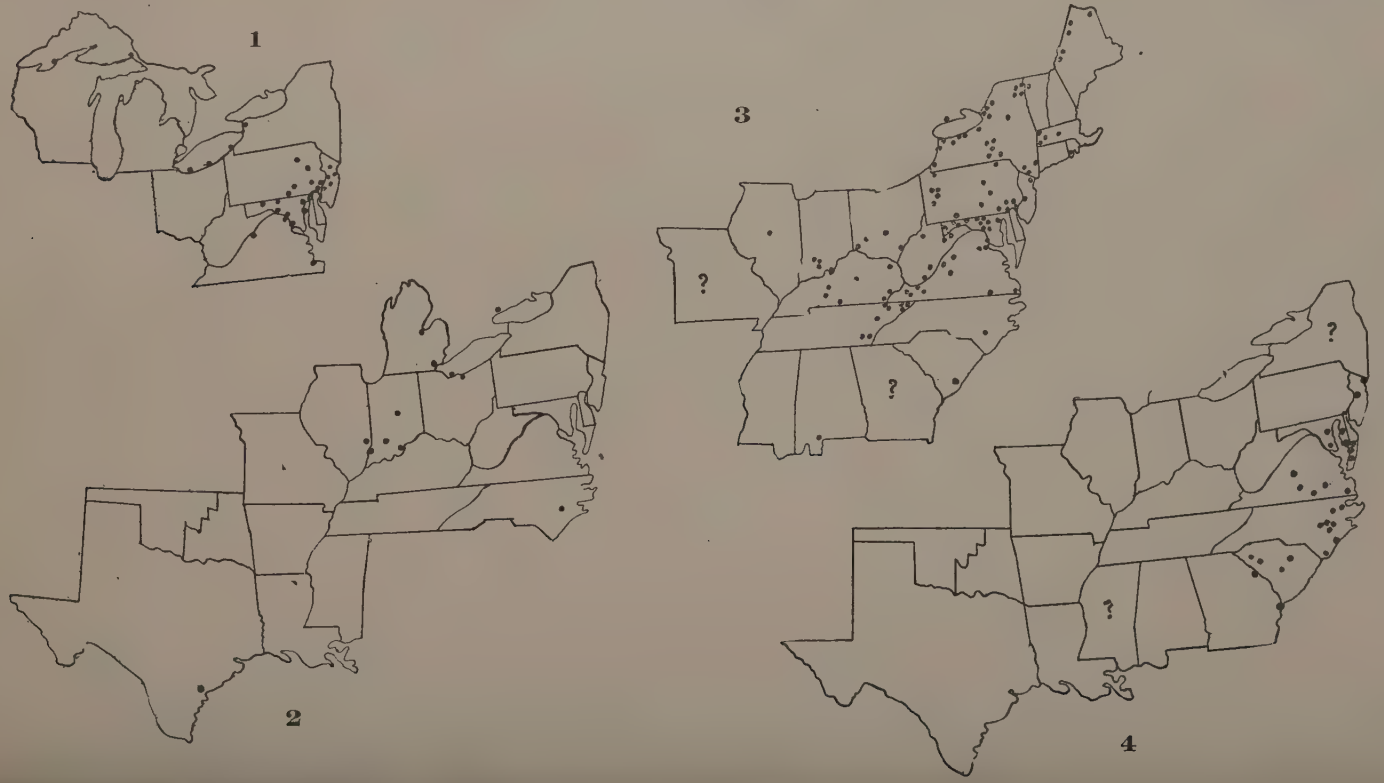

PLATE IV.

Distribution of *Cambarus.*

FIG. 5.—*C. blandingii acutus.*

FIG. 6.—*C. carolinus.*

FIG. 7.—*C. diogenes* and *C. diogenes ludoviciana.*

FIG. 8.—*C. gracilis.*

PLATE IV.

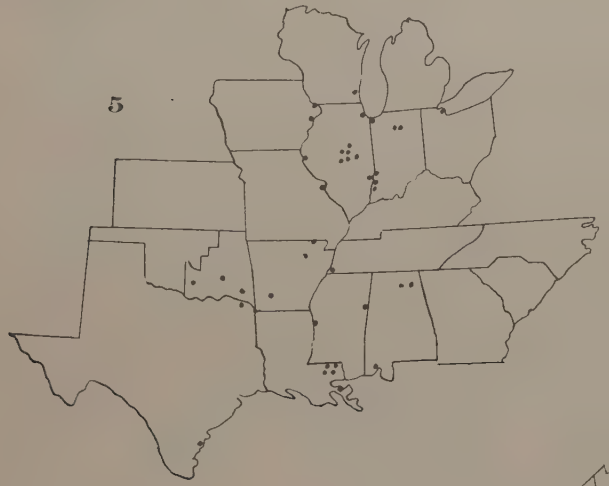

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PLATE V.

Distribution of *Cambarus*.

FIG. 9.—*C. immunis* and *C. immunis spinirostris* (excepting questionable Mexican locality).

FIG. 10.—*C. neglectus*.

FIG. 11.—*C. propinquus* and *C. propinquus sanbornii*.

FIG. 12.—*C. rusticus*.

FIG. 13.—*C. simulans*.
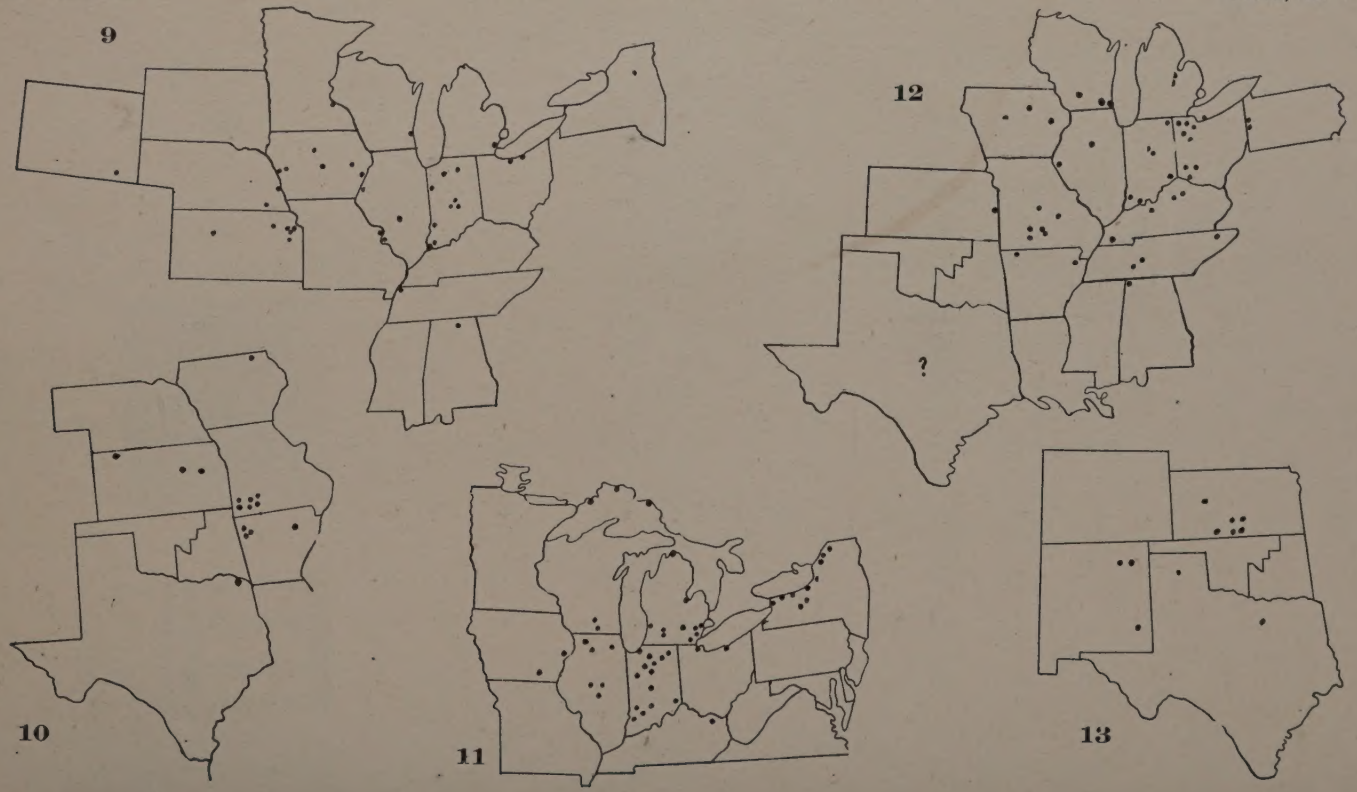
PLATE V.